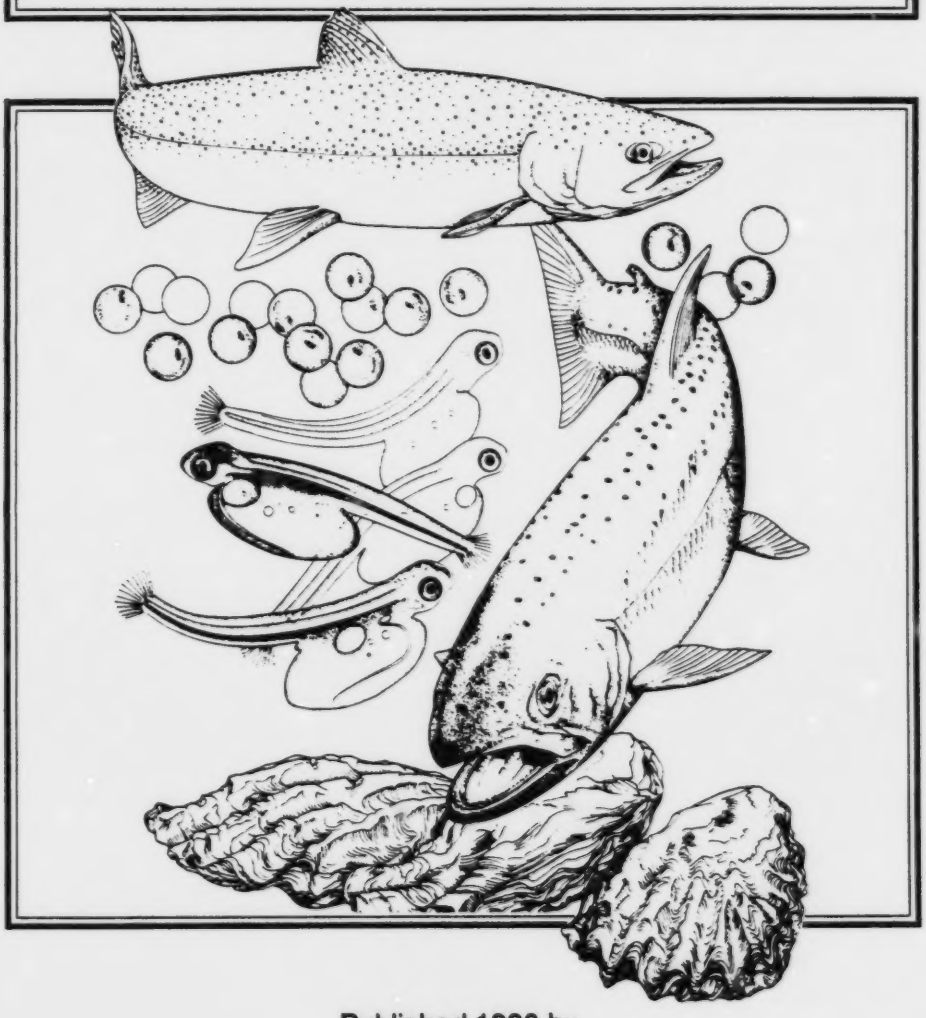
Aquaculture Industry Development Report

A Guide to the Design, Construction, & Operation of a Bivalve Shellfish Depuration Facility for British Columbia



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A Guide to the Design, Construction, & Operation of a Bivalve Shellfish Depuration Facility for British Columbia

by

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PREFACE

Depuration is by nature a technical process, and technical terms are often required to discuss it. In this manual, we have attempted to limit the use of technical terminology so that the concepts presented could be understood by most people. However, there remain some terms which require clarification. Many of these are Latin names of shellfish species. Excellent definitions and descriptions of these species, together with their common names may be found in "Marine Invertebrates of the Northwest Pacific", by Eugene Kozloff and published by the University of Washington Press. This book may be found in any library.

We have made no attempt to standardize units of measure in this manual. Instead, we have adopted the units of measure most popular within the topic being discussed. Units of water flow, volume, or the weight of shellfish are often measured in both English and metric units, and in these cases both are given. However, the cost per square foot is still a common currency in the construction trade, plywood still comes in 4'X8' sheets, and concrete blocks are still measured in inches. All plans and drawings relating to the construction of a depuration facility are therefore given in feet and inches and are not complicated with trivial conversions to metric equivalents.

With respect to metric units of measurement, a few abbreviations require definition:

um: micrometer; one-millionth of a meter
nm: nanometer; one-billionth of a meter
kg: killogram(s)
L: liter(s)

We wish to acknowledge the support of the Ministry of Agriculture and Fisheries whose funding has created the opportunity for this report. In particular, we wish to thank Mr. Bob Cox and Mr. Bill Roland for their valuable consultation and reviews of the drafts. We wish to express our sincere thanks to Mr. Dave Graham, Shellfish Specialist, and Mr. Glen Gibbard, Engineer, both with the federal Fish Inspection Branch of the Department of Fisheries and Oceans, for their efforts with respect to technical support and consultation. We thank the British Columbia Oyster Growers' Association for their constructive consultation, and Ms. Olive Alcock, their secretary, for her valuable logistical support. The timely contributions of Mr. Norm Gibbons of Redonda Sea Farms Ltd. are gratefully received. Finally, we would like to thank the many individuals who took the time and consideration to respond to our questionaire on this subject.

INTRODUCTION

Bivalve molluscs are filter feeders. Consequently, commercially harvested species found near centers of human activity are often found to contain impurities which can cause disease outbreaks among consumers. Such impurities include bacterial and viral pathogens originating primarily with raw sewage. **Shellfish purification** or **depuration** is the process of reducing the levels of such contaminants in shellfish before releasing them to markets. The focus of this report is confined to the depuration of bivalve shellfish contaminated by exposure to sewage effluent.

Strategies for depuration fall into two major categories. Common to both is the placement of the shellfish to be treated in seawater free of contaminants, where they can continue to feed and effectively displace contaminants from the digestive tract. In the simplest strategy, known as **relaying**, contaminated shellfish are transferred to another area where natural conditions satisfy depuration requirements. A more complicated method is **controlled depuration**, typically a land-based operation using sterilized seawater. A variety of sterilizing agents are available, including chlorine, ozone, iodophors, ultraviolet light, and ultraviolet-induced ozone. These agents are employed in conjunction with a range of flow systems and holding facilities. Permutations and combinations of these system elements may be found in depuration plants worldwide.

The critical feature of the depuration process is the evaluation of its efficiency. While a number of different classes of contaminants of shellfish are harmful to humans, depuration (in Canada) is permitted only for the specific purpose of decreasing enteric pathogens to acceptable levels. Depuration has not been extended to the removal of,

for example, PSP toxins or heavy metals. Currently, levels of shellfish contamination are estimated using the numbers of fecal coliform bacteria present in the meats as an indicator. Stringent sampling programs accompany depuration to ensure consistent product quality before, during and after the process. The sampling schedule, bacteriological testing, and quality criteria to be met are specified (in Canada) by the Inspection and Special Services Branch of the Department of Fisheries and Oceans (DFO).

In this manual we review shellfish depuration with a view to providing guidelines for the design, construction, and operation of a modern depuration facility in British Columbia. Industry members were interviewed to ascertain the demand for such a facility, and to determine plant capacities required to meet the needs of the small, medium, and large shellfish producer. This guide was prepared to fullfill the requirements of the Engineering Department and the Fish Inspection Branch of DFO. While a comprehensive bibliography is included, the majority of the information presented derives from recent reviews by Canzonier (1982,1984) and Richards (1988), as well as manuals similar to this by Furfari (1982) and Howell and Howell (1989). The details of design and construction in this manual are those formulated in Howell and Howell (1989) for one of the newest facilities in North America, operated by the Spinney Creek Oyster Company in Maine. Any company or individual considering depuration as a means of extending or supplementing their shellfish production should refer to the Spinney Creek Manual for additional details.

In reviewing this literature it has become apparent that there are likely to be many changes to the process and regulations governing depuration in the next

decade. This will arise from a greater focus on identifying new marine pathogens, increasing levels of pollution, and formulating increasingly sensitive assays for the presence of contaminants in seafoods. We have arranged this manual into discrete sections, to be bound in looseleaf format to facilitate updating in particular areas.

1.0 GENERAL PRINCIPLES

1.1 Historical Perspective-

Disease outbreaks attributable to the consumption of contaminated shellfish have been recognized for more than a century. Early investigations implicating contaminated shellfish examined cholera and typhoid fever (Ingersoll, 1881; Belding and Lane, 1909; Herdman and Boyce, 1899; Marvel, 1902). Herdman and Boyce (1899) showed that sewage-related bacteria levels in shellfish were quickly reduced by confining the animals in tanks filled with clean sea-water. Relaying experiments by Johnstone (1908; 1914) showed mussels reduced sewage bacteria levels by 99.6% after 72 h. Oysters in France were similarly depurated using filtered seawater (Fabre-Domergue, 1912) and with calcium hypochlorite (chlorine) sterilized water (Wells, 1916). Sewage bacteria levels were reduced by 98.5% in mussels within 96 h. in a flow-through system developed in England (Johnstone, 1914). UV sterilization was found to be generally effective in reducing bacteria and viruses (Chang et al.,1985; Fogh, 1955; Hill et al., 1970) and is now in widespread use, particularly in the United States. Depuration is now mandatory in Spain, Italy, and Australia.

Species depurated in quantity in Europe include mussels (Mytilus edulis), Portugese oysters (Crassostrea angulata), and the European flat oyster (Ostrea edulis) (Wood, 1966). Hard-shelled (Mercenaria mercenaria) and soft-shelled clams (Mya arenaria) are the principal species depurated on the eastern seaboard of the United States and Canada due to their economic advantage over other species (Richards, 1988).

Experimental and pilot depuration projects have been conducted only for Pacific oysters (Crassostrea gigas) and Native Littleneck (Protothaca staminea), Manila (Tapes japonica), and butter clams (Saxidomus giganteus) in British Columbia (Devlin and Neufeld, 1971; Neufeld et al., 1975). Such research and pilot projects are required prior to acceptance of depuration of other species by the Fish Inspection Branch (Appendix A). An experimental Pacific oyster (Crassostrea gigas) depuration facility was established in the early 1970's at Ladysmith, British Columbia (Devlin and Neufeld, 1971). A period of improved water quality in following years pre-empted further use of this facility. A commercial scale land-based shellfish depuration plant was built at Sooke, British Columbia, to depurate Manila (Tapes japonica) and Native littleneck (Protothaca staminea) clams harvested from Sooke Harbour. This is currently the only operating depuration plant in British Columbia.

Coastal pollution in many areas of the world has led to shellfish contamination levels which warrant permanent closure to wild fisheries. Sewage-borne bacterial contaminants are used as an indicator of contamination levels in both the United States and Canada. American guidelines established in the National Shellfish Sanitation Program Manual of Operations[1] state that shellfish should not be harvested from areas containing >700 total coliforms per 100 mL seawater or >88 fecal coliforms per 100 mL of seawater. Values above these result in complete closure to harvest. Areas showing lower levels may be opened under permit to relaying or a depuration facility. Canadian rejection criteria for depurated shellfish (DFO, 1988;

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[1] The criteria given here are taken from the U. S. National Shellfish Sanitation Manual of Operations, Part 1: Sanitation of Shellfish Growing Areas, 1988 revision. A Canadian version of these regulations- the Canadian Shellfish Sanitation Program- closely parallels the NSSP Manual and is currently in its draft stages. Accordingly, some of the figures given here may require revision in the near future.

Appendix A) are >170 fecal coliforms/100 g or no more than 10% of samples >130 fecal coliforms/100 g.

Recent declines in water and shellfish quality have led to eighteen temporary seasonal closures and some one hundred and three permanent closures within the seventeen fisheries management areas in the South Coast area of British Columbia (Dept. of Fisheries and Oceans, 1988). Some of these areas- Sooke Harbour, Sooke Basin, and Patricia Bay- have been opened for processing by the depuration facility operated by Cooper's Cove Oyster Farm Ltd. Other locations within the province are closed and re-opened as sampling and analysis dictate. Viability of shellfish depuration in British Columbia would be based on the assumption that many of the areas now permanently closed due to high levels of microbial contamination could be harvested via a permit to licenced depuration facilities.

1.2 Biological Parameters-

Depuration requires considerable additional product handling. This results in increased stress and mortality. In order to minimize product loss, gentle handling and a minimum of transport time are important. Other factors to be considered are summarized in Table 1. The most critical of these concerns is process water quality, specifically temperature, salinity, pH, and oxygen content. Salinity and temperature should closely approximate conditions at the harvest site, oxygen concentration should be at least 50% saturation (5.0 mg/L minimum), and pH should be between 7.0 and 8.4. Unless these conditions are met, shellfish will not actively "pump" and the purging of contaminants from their digestive tract will not be effective. Marginal values

TABLE 1

BIOLOGY OF SHELLFISH PURIFICATION[1]

Biological System	Function	Purification Process Considerations
1. Excretory	Feces production	Treated seawater should contain food to enhance purging of the gut; minimum turbulence in treatment tanks to prevent recontamination of shellfish with purged contaminants
	Pseudofeces production	Turbidity factor
	Diapedesis	Elimination of pathogens from the blood stream
2. Nervous	Detection of and response to external stimulus	Maintenance of proper temperature, salinity ($\pm$20% median salinity at harvest site), dissolved oxygen ($\geq$50% saturation or 5 mg/L minimum)[2], and pH (7.0-8.4) to maintain sufficient activity for depuration.
3. Respiratory (gills)	Water transport ("pumping") for oxygen uptake and feeding	Adequate dissolved oxygen levels; low turbidity to prevent gill clogging
4. Musculoskeletal (adductor muscle, siphon, hinge, and ligament)	Opening and closing of the shell	Proper layering of shellfish in baskets in the depuration system
5. Reproductive	Spawning	Spawning during depuration produces turbidity; shellfish may be inactive immediately after spawning, reducing depuration efficiency

1. Revised from Furfari, 1982.
2. Howell and Howell (1989) suggest 75% saturation is preferred.

of these parameters will increase stress levels and mortalities.

Pumping and purging activity is also inhibited by "overstacking" the animals in the depuration system and therefore regulations have been formulated which specify the depth of stacking in depuration trays. Oysters and hard clams are particularly affected as they rely on the elastic properties of the hinge ligament to open the valves; stacking animals too deeply will prevent those on the bottom from opening and purging. Consequently, a maximum stacking depth of 8 cm (3") is required for oysters. Soft clams are somewhat less sensitive (they are much larger): 20 cm (8") depth is permitted. Overall, stacking strategy should be such that shell opening is not restricted by the weight of the shellfish, and contaminants expelled from upper (outer) animals does not acummulate on (and recontaminate) lower (inner) animals. Regardless of the species or the stacking arrangement within the depuration system, there should be uniform circulation throughout the tank. Turbulence is to be avoided, however, as this will resuspend expelled feces (and hence contaminants) and allow them to recontaminate purged animals.

Different species depurate at different rates. The rates of uptake and depuration of a variety of pathogens in a wide range of species are exhaustively reviewed by Richards (1988). For simplicity, this manual is confined to clams and oysters, which take 24 to 48 hours to reduce fecal coliforms to acceptable levels. The reader should refer to Richards (1988) for guidelines regarding other species.

1.3 Sources of Shellfish for Depuration-

In Canada, a Memorandum of Understanding (MOU; see Appendix A) between the depuration plant operator and the DFO Fish Inspection Branch is required prior to the issuance of a permit to harvest from a marginally polluted closed area. Three conditions must be satisfied before the permit may be issued: 1) acceptability of the harvest site; 2) approval of the purification facility and methods employed; and 3) acceptance by the operator of responsibility for the entire depuration process and quality control of the shellfish from harvest to final release after verification of purity.

A depuration facility may process shellfish harvested from only one area under permit at a time. Harvest site approval must be obtained for each prospective site. They must meet the following criteria: 1) Records are consulted by the Fish Inspection Branch to ascertain the reason for the closure and sources of contamination. If records for the site are not recent, an inspection of the site may be required to identify potential contaminant sources. During the period of worst pollution at the site, water must not contain a fecal coliform median MPN in excess of 88 per 100 ml, and no more than ten percent of the water samples may exceed fecal coliform MPN of 260 per 100 ml.

Initial sampling at the site for contaminants will be supervised by the DFO Fish Inspection Branch. Samples obtained from various areas and intertidal heights will be analyzed for bacteria individually. Samples may be pooled for chemical analysis unless heterogeneity is suspected. No shellfish samples will exceed 2300 MPN fecal coliforms/100 g. If any sample exceeds this criterion the site will be rejected. Shellfish exceeding this criterion are not safe to depurate, as they may harbour other

pathogens in unsafe numbers. The presence of radionuclides, excessive trace metals or toxins is also grounds for rejection of the site. Further terms for the issuance of a harvest permit by the Fish Inspection Branch are presented in Appendix A.

1.4 Limitations of the Depuration Process-

Although the use of this process is widespread and mandatory in several countries, depuration has several unresolved limitations (Canzonier, 1982). Given healthy shellfish which are lightly contaminated by sewage bacteria in mantle cavity and gut, and a properly designed, operated and managed depuration facility, the depuration process can greatly reduce risk to public health by enteric bacterial diseases and afflictions from raw shellfish consumption. Viruses associated with the gut and mantle are also shed along with bacterial pathogens, reducing the risk of enteroviral diseases. Viral loads sequestered in other parts of the shellfish are not shed at rates high enough to be significantly reduced in the short time frame necessary for commercial operations (Canzonier, 1982; Richards, 1988).

Shellfish which have initial bacterial loads in excess of certain limits may not effectively depurate (Canzonier, 1982). As bacterial tests used for assessing shellfish quality are only indicators, not an absolute measure of contamination, shellfish may, after processing, remain unfit for human consumption. For instance, indigenous marine bacteria like Vibrio, a causative agent of gastroenteritis, do not depurate well (Barrow and Miller, 1969) and may even multiply within a depuration system as they may not be destroyed by UV treatment. However, shellfish have been depurated from Vibrio in 16 days (Kelly and Dinuzzo, 1985). Canzonier (1982) and Richards (1988)

have described cases of viral hepatitis and other illnesses resulting from the consumption of shellfish which have passed microbial testing standards after depuration or relaying to clean water sites.

Substances other than viruses also may not be eliminated rapidly enough during depuration. These include the PSP toxins, pesticides, heavy metals, hydrocarbons, (Canzonier, 1982) and radionuclides (Richards, 1988). PSP toxins originating with dinoflagellate algal blooms may also be incorporated and sequestered in various shellfish tissues. While it is known that as background water concentrations decline after such blooms, PSP levels in shellfish eventually are reduced, the long residence time and slow release of these toxins preclude their economical depuration. Under experimental conditions only, Blogoslawski and Stewart (1977, 1978) demonstrated that crude PSP toxins could be deactivated in shellfish with ozonated seawater. However, commercial PSP depuration cannot be applied due to the great risk to public health of a single failure.

It must be stressed that depuration or controlled purification increases the cost of shellfish production. Canzonier (1982) reported that, based on large scale operations in Spain, depuration adds at least 16 to 20% to the cost of production. In the British Columbia industry where profits are often marginal this is a serious consideration, particularly for the small growers. Before pursuing depuration, careful examination of alternatives, such as relaying to clean water sites, is absolutely essential (Canzonier, 1982).

2.0 DEPURATION PLANT DESIGN

2.1 Site Selection and Seawater Supply-

Depuration facilities require a seawater source with salinity and temperatures similar to those of the grow-out or harvest site. This should be given primary consideration as significant deviations will result in physiological stress to the shellfish, reducing depuration effectiveness (Richards, 1988; see Section 1.2).

Ideally, the facility should be located at or near the processing plant. A waterfront location is ideal in terms of an easily available seawater supply and access to delivery of harvests by boat. The plant may not necessarily front directly on the water, reducing land costs, as long as easement is obtained for the passage of seawater intake lines. Alternative sources of seawater may be considered, such as salt-water wells wherever suitable intrusions occur (Canzonier, 1984). Proximity to major electrical supply lines is important; the majority of equipment specified below requires only 120 volts, but the main seawater supply pump will be more efficient if it is 220 volt, three phase. Zoning bylaws and cost of waterfront property must be considered very carefully. Howell and Howell (1989) have emphasized the evaluation of potential species and shellfish sources inorder to select a site. Additional site considerations may be reviewed in consultation with DFO.

Seawater quality should be investigated to determine whether any potential problems may exist which will affect depuration effectiveness. Temperature, salinity, silt, and suspended matter (turbidity), dissolved oxygen, and pH should be evaluated. An adequate supply of potable water is required for washing, as well as electricity and waste disposal sites or services.

Distance to major transportation routes and markets must also be considered; this is particularly relevent to the British Columbia industry, which is geographically widespread. Potential pollution sources such as other industries, waste treatment plants, and outfalls in the vicinity are important. Consideration of annual fluctuations in the characteristics and quality of the seawater supply is important to ensure that the plant can operate year round. It is strongly advised that testing of these parameters cover at least a range of tidal activities as well as seasons.

2.2 General Construction Considerations-

Construction of most depuration plants has followed the guidelines of Furfari (1966). Additional recent design guidelines are presented in Canzonier (1982, 1984), Furfari (1976), Neilson et al. (1978) and Howell and Howell (1989). These papers should be consulted by those seriously considering pursuing depuration. Table 2 summarizes the components common to most depuration systems. Figure 1 presents a diagram of a simple flow through system using UV sterilization.

Plant structures will require protection from the elements, heating for offices, culling, washing and packing facilities, restrooms, water treatment equipment area, refrigeration, and general storage (Canzonier, 1984). Sedimentation tanks and sterilization equipment, depending on the type, may be located outside. Plant structure must comply with the construction requirements of Schedule I, Parts I and IV of the

Figure 1: A Basic Flow-Through Depuration System

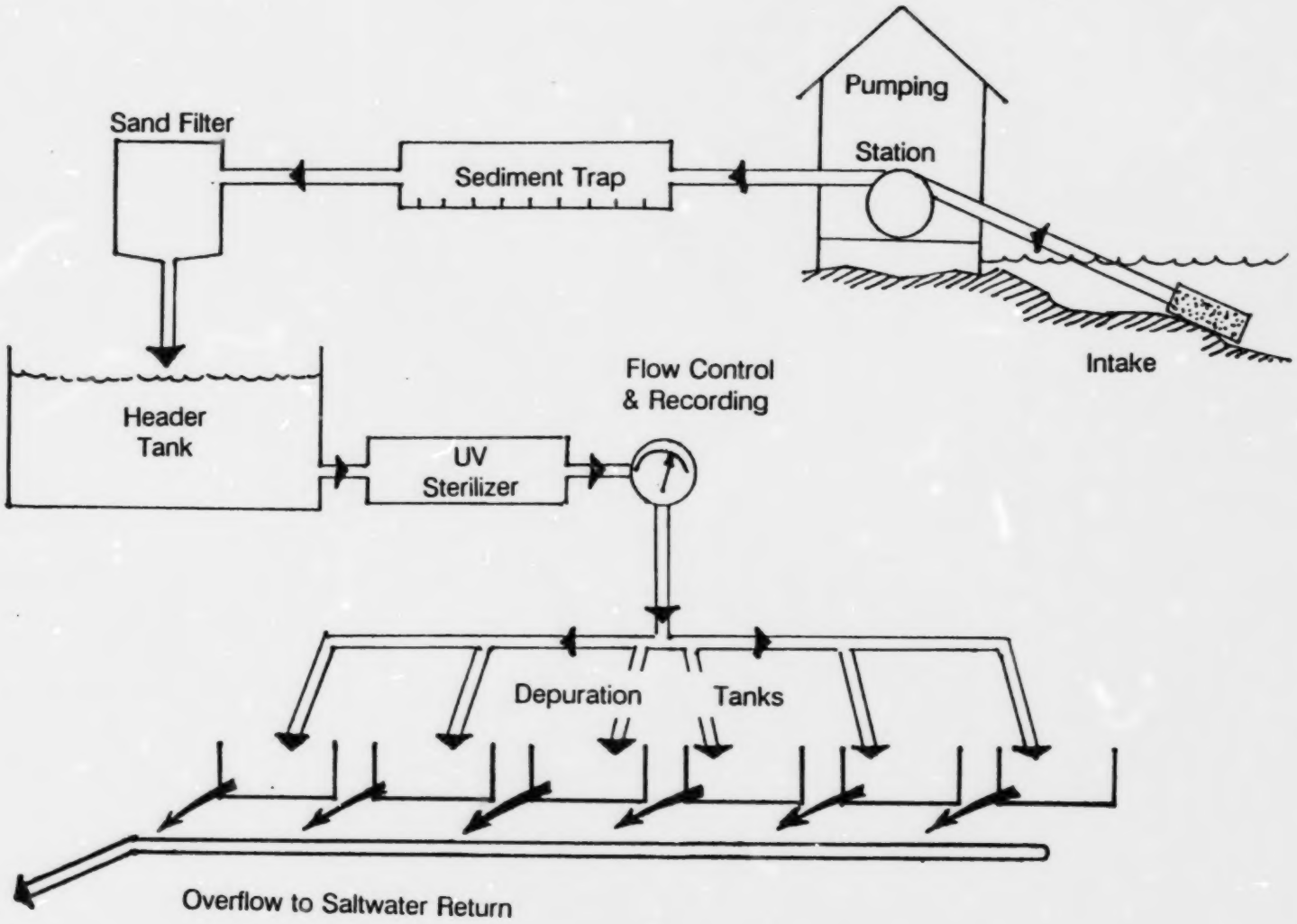


TABLE 2

PURIFICATION PLANTS

PROCESS AND PRODUCT COMPONENTS[1]

PROCESS	COMPONENTS	CONSIDERATIONS
Seawater supply	*Intake	Pier or wharf
	Saltwater well	Testing required
	*Pump station	Required capacity; lift; priming; corrosion; standby
	*Piping, valves	Sizing; fouling and clean-outs; tanks
	Artificial seawater	Storage tanks; recirculation
Seawater treatment	Settling basin	suspended sediments
	Sand filter	turbidity; backflushing;
	*UV or ozone generator[3]	coliform levels (MPN[2]) $\leq$2/100 mL
	Aeration	minimum turbulence;
	monitoring	
Purification	*Tank(s)	Number; size; capacity;inflow/ outflow; drain; materials; convenience for cleaning; arrangement
	*Flow measurement	
Shellfish storage	*Refrigeration and drainage	Separate for treated/ untreated shellfish
Shellfish wash/cull	*Hose fixtures	Water pressure; freshwater; treated seawater; backflow prevention
	Cull table or conveyor	
	Wash/cull machines	

---

* These are essential items for all depuration plants
1. Revised from Furfari, 1982.
2. "MPN" is the Most Probable Number assay for the presence of coliforms.
3. While ozonation is a popular sterilizing agent in many parts of the world, the United States Food and Drug Administration considers ozone a food additive in the context of depuration and currently does not accept the process. Canadian acceptance currently awaits further testing of ozonation for depuration purposes.

Fish Inspection Regulations which can be obtained from DFO. An important consideration often mentioned in the literature and required by DFO is that **separate storage must be provided for incoming undepurated shellstock and purified product.** A definite physical barrier between these two areas is mandatory to prevent cross-contamination of purified product (Canzonier, 1984). If the depuration plant is annexed to a processing plant, some of the existing facilities in the processing plant (for example, separate cold storage) may be useful to the depuration facilities. **Fish Inspection Regulations should be consulted in detail prior to planning construction and seeking approval from the Fish Inspection Branch.** A number of suggestions regarding construction practices gleaned from the literature follow.

As volume and supply continuity of shellstock determine economic feasibility and success in depuration, very serious deliberation must be given to the size and volume capacity of the system. The facility must not be too small nor too large for the volume of shellstock to be depurated. It is essential to have sufficient storage in the form of temperature controlled rooms and seawater tanks to provide sufficient reserve to keep the plant operating at capacity at all times. The modular approach to system design presented in the Spinney Creek Manual (Howell and Howell, 1989) is particularly attractive in solving these problems.

All shellfish handling areas, depuration tanks and storage such as refrigeration should be on the ground floor if the building is more than one storey high. All walls in wet areas must be faced with impermeable, non-corrodible, easily washed material. Masonry coated with epoxy resin finishes are most suitable. Others prescribed by DFO for fish processing plants are also acceptable.

Flooring must be constructed of reinforced concrete, incorporating a latex bonder and should be finished with a non-skid coating or left as raw concrete. Expansion joints of butyl-epoxy, placed as strips during pouring of the concrete or poured into spaces left between concrete slab sections, must be incorporated into concrete floors. Asphalt-felt expansion strips should be avoided as they will be likely to harbor bacteria (Canzonier, 1984). Floors must be sloped and incorporate a drainage system of sufficient capacity to handle flow from the simultaneous draining of all tanks. Floor drains should also be equipped with a settlement trap to prevent plugging with refuse such as discarded shellfish valves or culls.

Tanks, plumbing, and instrumentation must be constructed of corrosion-resistant materials that can be easily cleaned and maintained. UV water sterilizers must be equipped with a solenoid valve or pump shut-off switch which shuts down water flow should the sterilizer fail. This safety valve should be located at the intake end of the sterilizer to prevent hydrostatic shock damage to the sterilizer. Plants should be capable of routinely assessing temperature, salinity, turbidity, and dissolved oxygen to provide optimum depuration conditions for shellfish. Operating procedures must be established to maintain depuration efficiency. Procedures must include monitoring tank flow rates, regular tank washing, and shellfish washing and culling routines (Richards, 1988).

To summarize, the main components of a basic depuration system and considerations which must be addressed are:

1) Selection of a suitable site and seawater supply;

2) Building design and capacity;

3) Seawater delivery equipment;

4) Sediment settlement traps and pre-sterilization filtration;

5) Seawater sterilization technology alternatives;

6) Process water quality and monitoring;

7) Depuration tank design and loading rates;

8) Product handling equipment; and

9) Flow regulation and distribution.

It is STRONGLY RECOMMENDED that design plans be submitted to DFO for approval PRIOR to beginning construction.

2.3 Plant Capacity and Design Plans-

2.3.1 Preferred Plant Capacities

A brief survey was conducted to determine appropriate sizes and demand for depuration facilities among members of the B.C.O.G.A., representing small, medium and large producers. Based on a production schedule of one lot depurated every 3 days or 10 lots per month with the plant operating 10 months per year, a plant should purify 100 lots per annum. A single tank holding 24 baskets of 30 lbs. shellstock each will depurate 720 lbs. per lot or about 1500 1bs/week (based on the Manila clam). The Spinney Creek Plant layout presented in Figure 2 has six tanks and therefore has the approximate capacity of 10,000 lbs per week. Expanded layouts of this modular format having 12 or 24 tanks, with capacities of 20,000 and 40,000 lbs per week, respectively, are presented in Figure 6. Capacities reflect the shellfish volumes which

can be processed but repeated sampling and culling will somewhat reduce final production volumes.

Although interest in a one tank depuration plant has been expressed, operation of such a facility would be hard to justify economically when capital outlay and operating expenses are considered. For this reason specific plans for a single tank depuration facility are not presented, although they would follow the same general layout as the larger plants.

2.3.2 Depuration Plant Plans

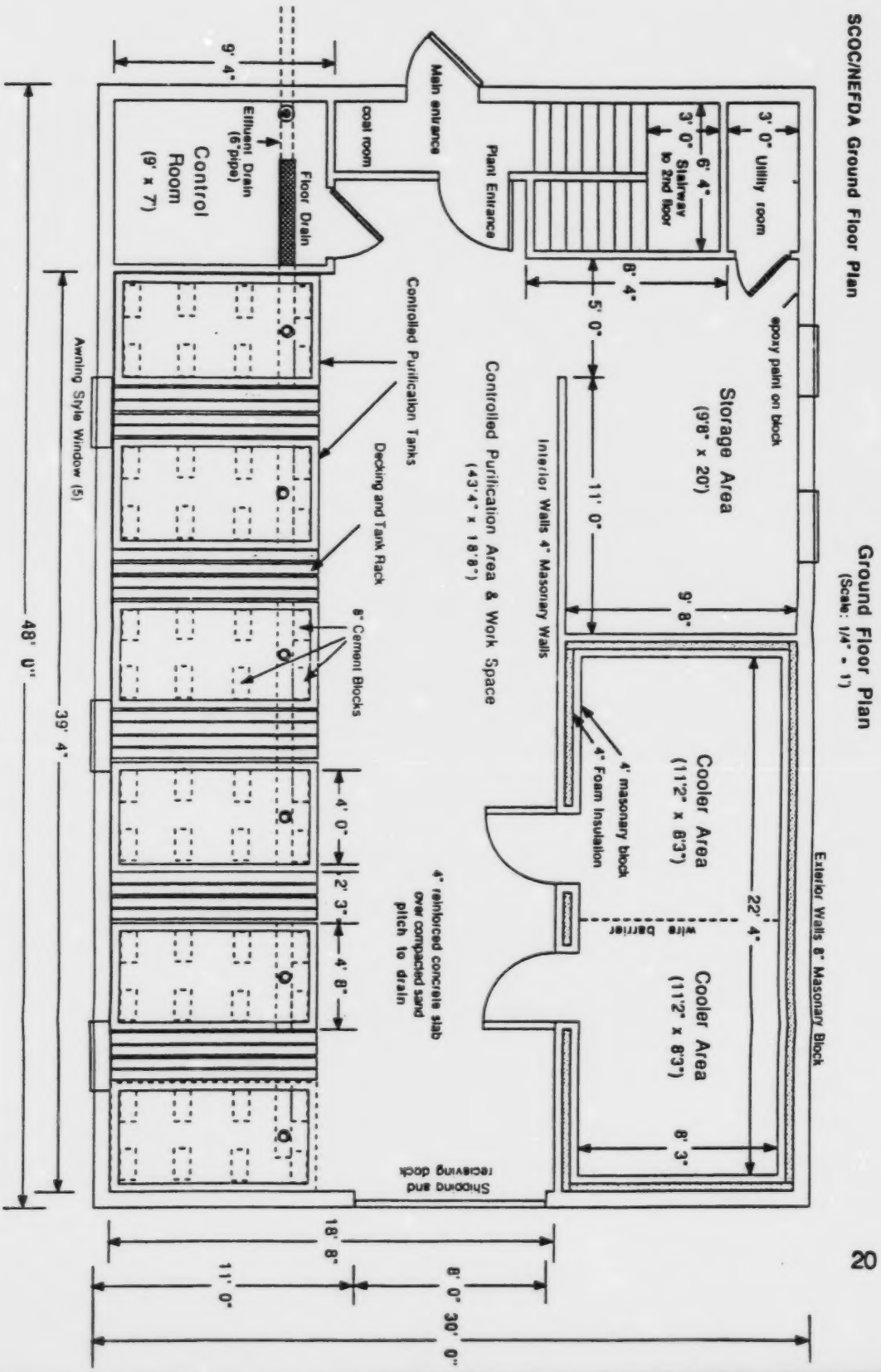
Howell and Howell (1989) designed a modular system for depuration facilities upon which the following designs and plans have been based (Figures 2-10). A valuable reference to keep on hand is Huguenin and Colt (1989), entitled "Design and Operating Guide for Aquaculture Seawater Systems".

The modular design presented below recirculates the sterilized water after each pass through the depuration tanks. This is achieved by draining the tanks into a recirculation line which feeds a reservoir tank, from which water is again pumped through the UV sterilizer. To maintain pH between 7.0 and 8.4, it is likely that a biofilter will be required in, or before, the reservoir tank. This filter has not been shown on the attached drawings.

The designs shown can be modified to a flow-through system quite easily. In a flow through system the sterilized water would only be used once. This would remove the need for the recirculation line and reservoir, and the relocation of the 1 h.p. pump to the line between the sand filter and the UV system. The tanks could be allowed to

Figure 2 Depuration Plant- ground floor plan

(From Howell and Howell, 1989)



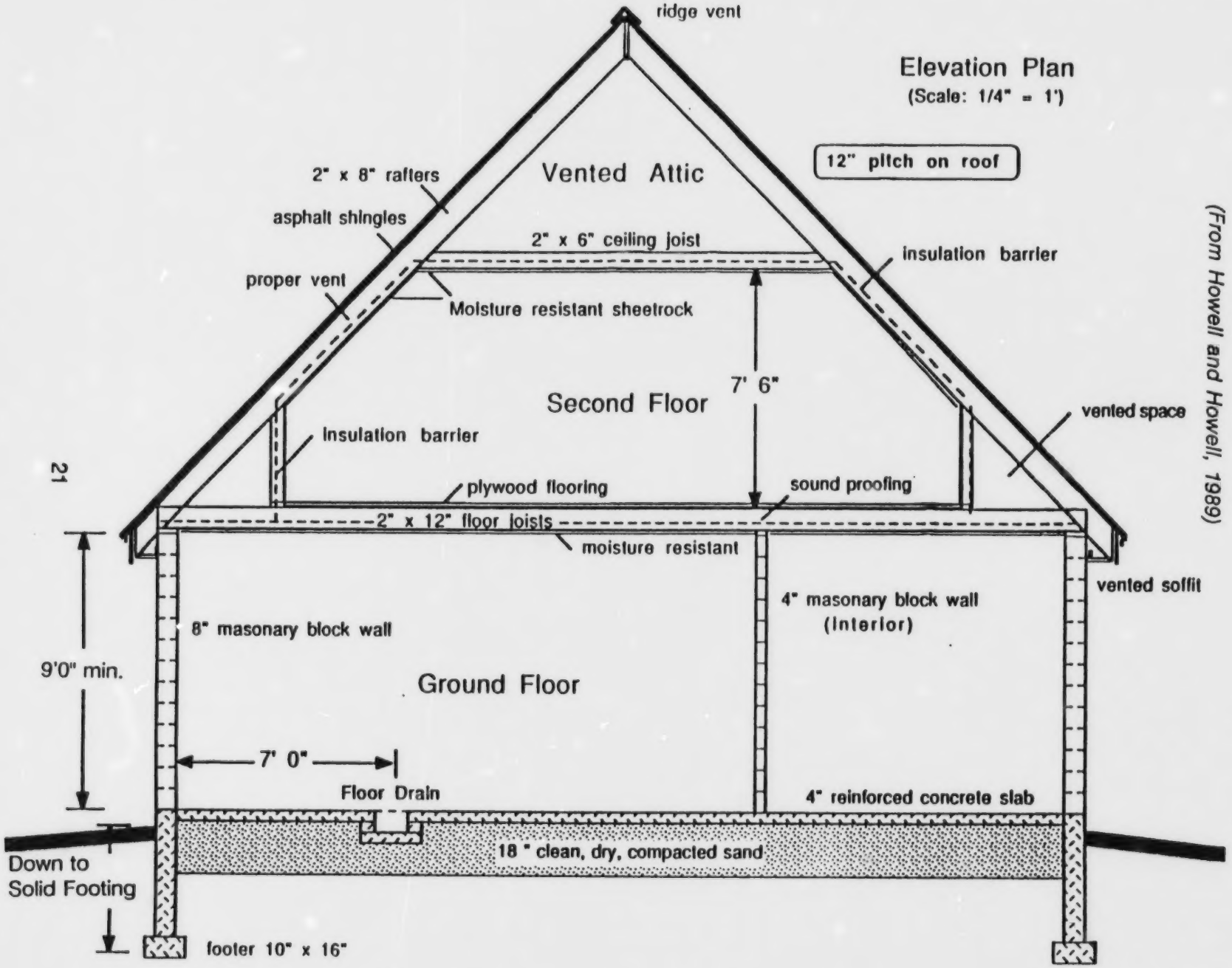


Figure 3 Depuration Plant- end view

(From Howell and Howell, 1989)

Figure 4 Depuration Plant- top floor plan

(From Howell and Howell, 1989)

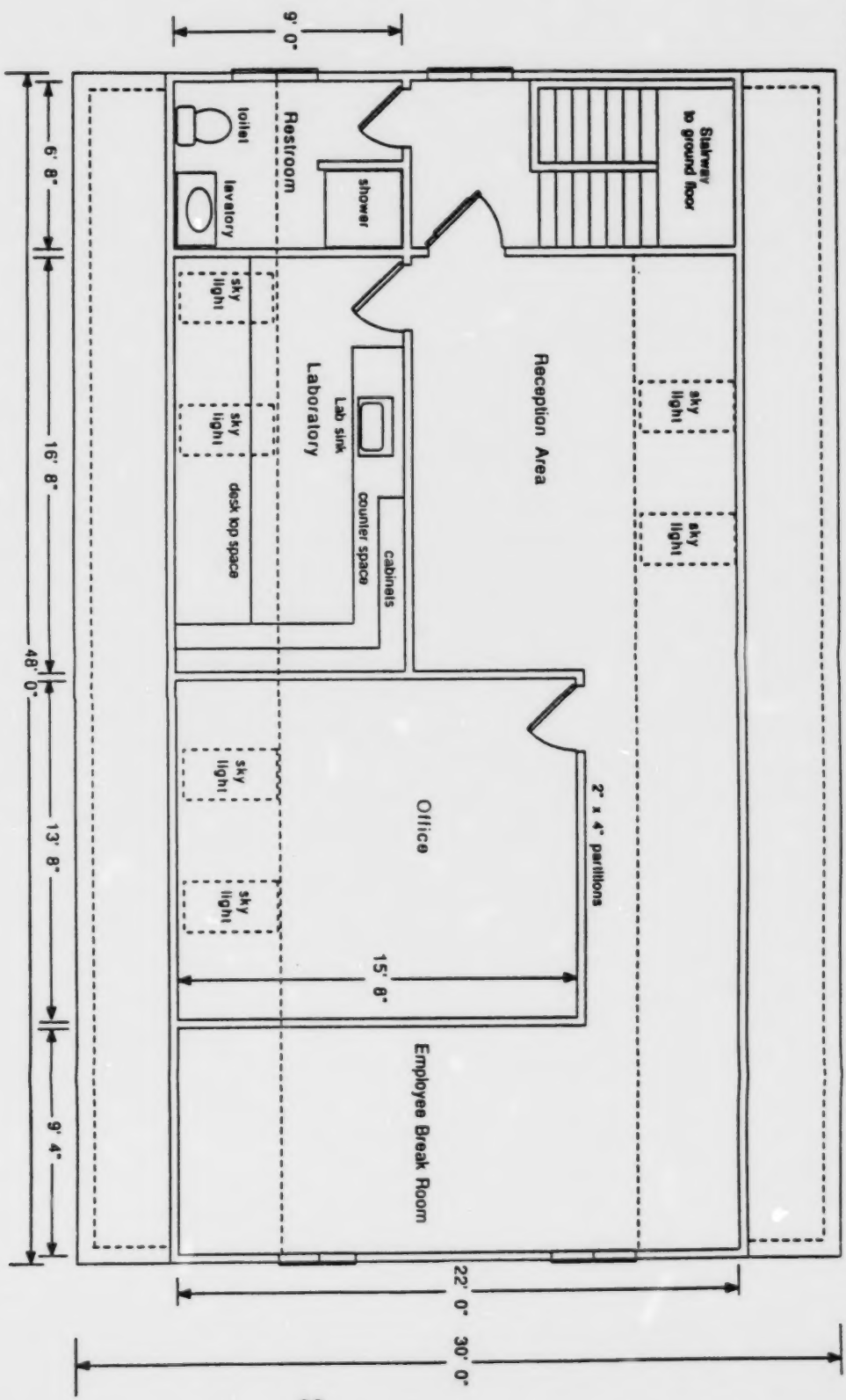


Figure 5 Depuration System- top view

(From Howell and Howeil, 1989)

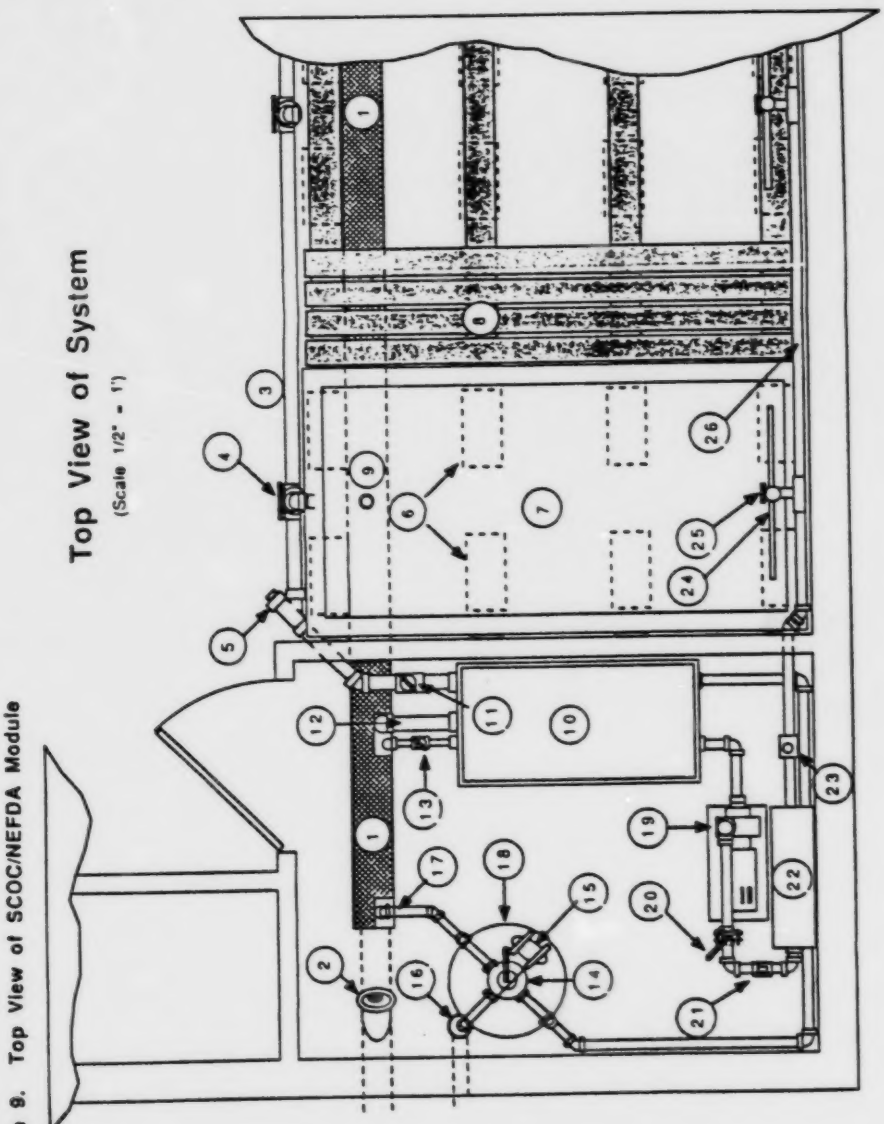


Figure 6 Depuration System- side view

(From Howell and Howell, 1989)

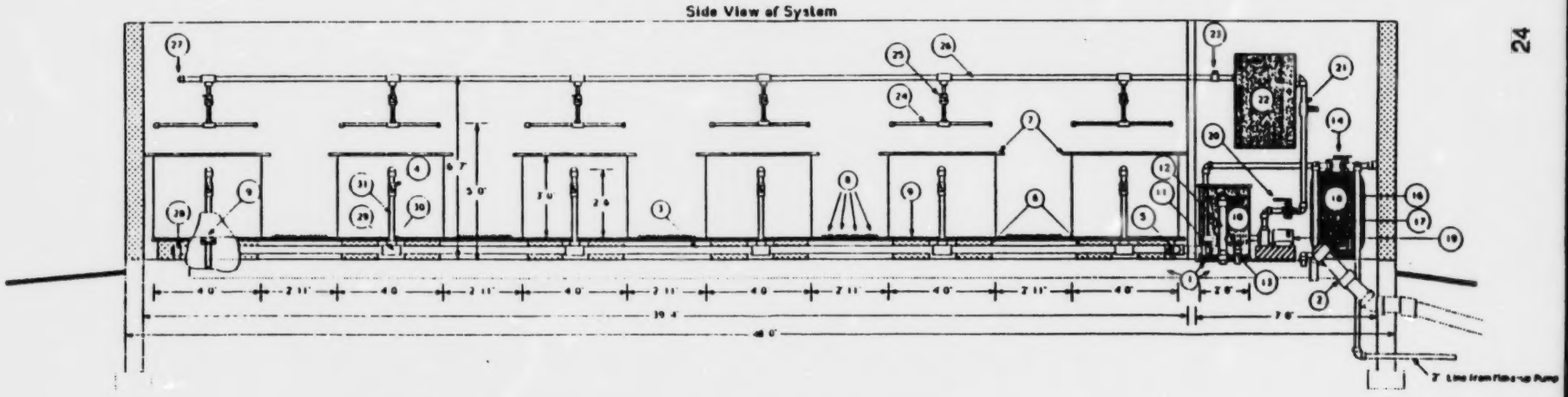


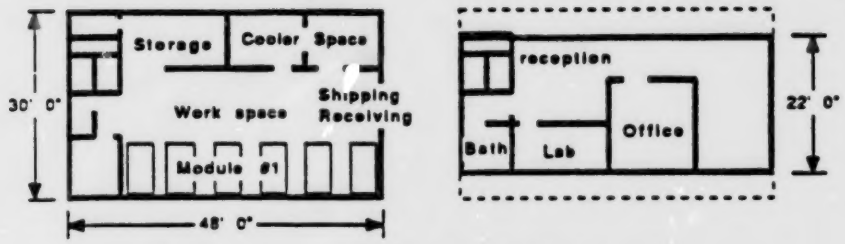
TABLE 3

KEY TO THE SPINNEY CREEK MODULE DESIGN

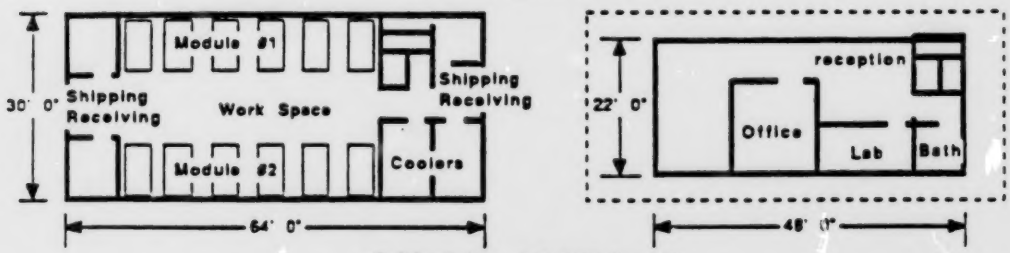
1. Floor Drain, 8"X8" grating in control room
2. Clean-out for 6" drain line to overboard discharge
3. 3" Return Line, pitched to resevoir tank
4. 2" Ball Valve on tank overflow line
5. 3" Clean-out for return line
6. 8" Cement Block to support purification tanks
7. Controlled Purification Tanks, 8'X4'X3', fiberglass
8. Deck, 1/4" aluminum treadplate
9. 2" Tank Drain, located over floor drain with stopper
10. Resevoir Tank, 2'X4'X30", with cover and tank adapters
11. Return Line Ball Valve, 3"
12. Resevoir Overflow, 3"
13. Resevoir Tank Drain, 2" line with 2" ball valve
14. 3-Way Valve on sand filter
15. Inspection Port for sand filter
16. 2" Make-up Line from source water pumping system
17. 2" Waste Line from sand filter used during back wash
18. Sand Filter used to remove particles greater than 20 microns
19. Recirculation Pump, 1 HP, 220 V, 100 GPM
20. 2" Butterfly Valve used to control recirculation flow
21. Flow Meter, 2" Pitot tube type
22. Ultraviolet Light Disinfection Unit, 100 GPM rated, 2" ports
23. Vacuum Breaker, 2", to protect UV unit
24. Aerator Head, 1" pipe with 1/8" holes at 1" spacing
25. 1" Ball Valve to regulate flow between tanks
26. 2" Feed Line to tank aerators
27. 2" Threaded Cap for cleaning feed line
28. 3" Threaded Cap for cleaning return line
29. 3" Tee
30. 3"X2" Bushing
31. 2" Overflow to return line

Figure 7 Larger Capacity Depuration Plant Designs

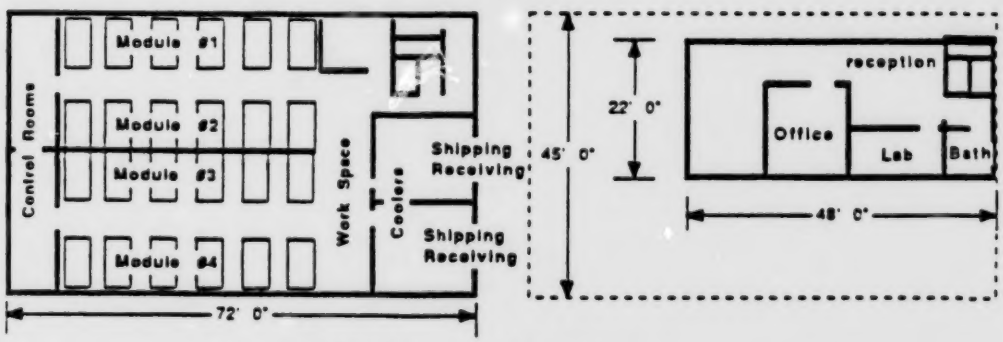
(Adapted from Howell and Howell, 1989)



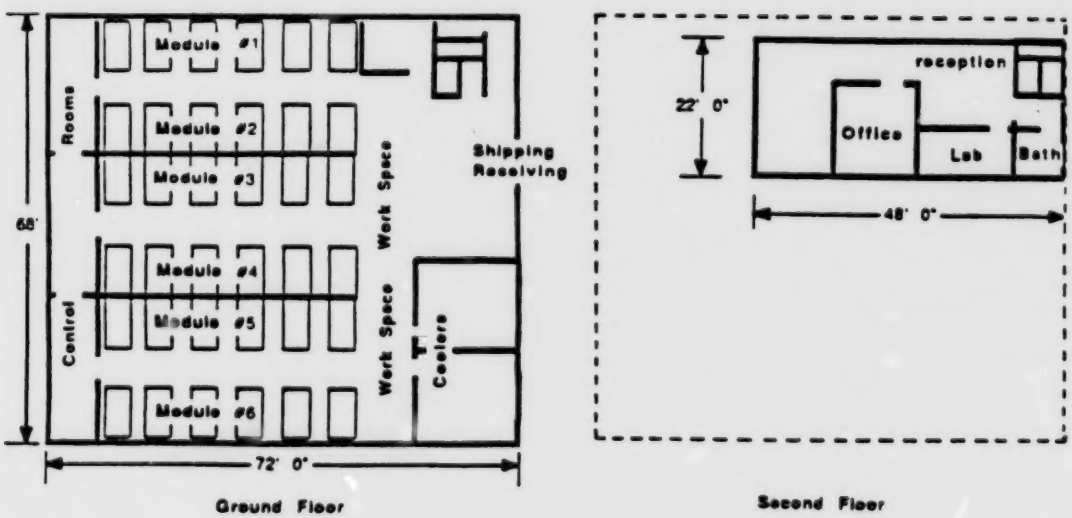
1 Module- 10,000 lbs/wk



2 Modules- 20,000 lbs/wk



4 Modules- 40,000 lbs/wk



6 Modules- 60,000 lbs/wk

drain over the end into the floor drain. This change would reduce the capital cost of the system, and result in more efficient discharge of floating detritus from the surface of the tanks. It would, however, mean that the operating costs of the main seawater supply pump would be higher, as this pump would be running continuously during the depuration cycle. For this reason, a recirculation system may be preferable in sites where seawater delivery over large distances or heights (e.g. over long tide flats) is required.

2.4 Seawater Delivery Equipment-

The location of the pump intake is important. For reasons of economy, the main pump should be located as close to the seawater source as possible. A steep natural shore or pier are ideal. Alternatively, an offshore platform at the appropriate depth to permit pumping at low tide may be feasible if navigation is not impeded. Broad tidal flats are inconvenient and the possibility of interference by logs and other floating debris must be considered. Floating intakes are also possible, although susceptibility to wide variations in surface salinities may be a problem in some areas.

Pumps and offshore platforms must be easily accessible for routine maintenance (pump servicing and intake screen cleaning) and repair. Drive motors should be three phase electric where possible. Cast iron centrifugal pumps are excellent but may require modification of seals and the shaft to resist corrosion. Plastic pumps are available and although expensive, they are very well suited to salt water applications.

Intake pipes should be constructed of non-toxic, corrosion resistant material such as polyvinyl chloride (PVC). Alternate lines should be considered in the event of damage or blockage of the main line. In British Columbia water blockage of seawater plumbing systems by organisms which thrive there is common. A foot valve and intake screen are necessary to prevent clogging and possible damage to the pump by seaweed and man-made debris such as garbage bags. Total lift should not exceed 9.5 m (32 ft); some pumps require less. The combination of larger pipe, less lift and shorter distance is better. To supply a six tank, 10,000 lbs per week facility, 100 gal/min at a 30 foot head is needed. The system must be capable of supplying a flow rate of 5 L/min for each 25 kg of shellfish (1 gpm/50 lbs).

2.5 Sedimentation Traps and Pre-sterilization Filtration-

If space is not limiting, a sedimentation trap installed prior to filtration can extend the life and reduce the maintenance requirements of filtration devices. This can easily be constructed by installing a tank or crib which will reduce the water velocity sufficiently to permit large suspended particles to settle. A small series of removable weirs in the bottom over which the water passes will facilitate settling.

Seawater filtration can be easily accomplished with a back-flushable, sand filter containing sand of uniform diameter. The Spinney Creek sand filter is 30" in diameter by 24" high and is filled with #18 grit sand to remove particulates down to 20 microns in diameter. The filter should be plumbed to allow for easy back-flushing on a daily basis and replacement of the sand as required. Swimming pool type sand filters capable of handling 100 gpm or more are available off the shelf for about $1200, with

backflushing valve. Care should be taken to ensure that the doorway of the control room is large enough to allow the filter to be removed, should this ever be required.

2.6 Seawater Sterilization Alternatives-

Depuration system waters have been disinfected by treatment with ultra-violet light (UV light), hypochlorite and chlorine, iodophores and ozone as well as UV generated ozone (activated oxygen) (Richards, 1988). Ultraviolet light sterilization is the preferred method in the United States and is probably the best and easiest system to use. Disinfection processes using chlorine, iodophores, UV light, ozone and UV generated ozone are discussed below. Table 4 summarizes the relative advantages and disadvantages of chlorine, ozone, and ultraviolet, the three sterilization agents in most common usage.

2.6.1 Chlorine

Chlorination is the oldest disinfection procedure (Carmelia, 1921; Wells, 1928; Richards, 1988). Chlorination has been shown to effectively reduce microbe levels, although viruses are less effectively inactivated than bacteria by chlorine (Richards, 1988). Chlorine is a very strong oxidant and must never directly contact shellfish tissue (Blogoslawski and Stevens, 1983). Even low levels of chlorine can affect pumping rates of shellfish (Dodgson, 1928). The oyster (Crassostrea virginica) ceases pumping at chlorine concentrations of 0.2 mg/l (Galtsoff, 1946). Therefore water which has been sterilized by chlorination must first be dechlorinated prior to use in depurating shellfish. Dechlorination is accomplished using sodium thiosulphate, or activated charcoal separately or in combination with aeration, before addition to

TABLE 4

SEAWATER DISINFECTION METHODS[1]

ITEM OF CONCERN	METHOD		
	UV	OZONE	CHLORINE
Initial cost	High	High	Low[2]
Operating cost	Moderate	Moderate	Low[2]
Maintenance	Moderate	High	Low[2]
Recirculating	Suitable	Suitable (residuals dissipate)	Residuals harm shell-fish
Flow-through	Suitable	Suitable (residuals dissipate)	Residuals harm shell-fish
Batch treatment	Suitable	Suitable	Suitable if neutralized
Affect on shell-fish activity	Very little	Usually little	Harmful (un-less neutra-lized)
Safety	Problematical	Problematical	Generally safe
Turbidity	Affects light penetration	No problem	No problem
Contact time for disinfection	Seconds	Minutes	Minutes
Test of treated seawater	None	Residual ozone	Residual[3] chlorine

1. Revised from Furfari, 1982.
2. More recent experience with ozone indicates that these comparisons are not accurate and that use of ozone is not as unfavourable as this Table indicates. Ozonation removes dissolved organic matter and increases oxygen levels in treated water.
3. Residual chlorine is probably harmful to the environment. Further assessment is required prior to implementation of either a chlorinated or ozonated system.

depuration tanks (Canzonier, 1982). However, excess sodium thiosulphate decreases the pumping activity of Pacific (C. gigas) and Olympic oysters (Ostrea lurida) relative to raw seawater (Kelly, 1961). Chlorine treatment is more labor intensive than other methods, but it has been the chosen method at many depuration plants for many years due to its reliable sterilization properties and ease of measurement of residual levels of chlorine (Blogoslawski and Stewart, 1983).

2.6.2 Iodophors

Iodophors enhance the permeability of bacterial cell walls to iodine and as a result enhance its bacteriocidal properties. Recirculating systems using 0.1 to 0.4 mg iodophor/L reduce bacterial concentrations rapidly without physiologically inhibiting shellfish nor affecting palatability (Fleet, 1978). Italy and several other European countries have used iodophors in depuration (Richards, 1988).

2.6.3 Ultra-violet Light

Radiation at a wavelength of 260 nm is lethal to bacteria. UV is also effective in reducing some viruses (Chang et al., 1985; Hill et al., 1970). For this reason UV light disinfection has been widely applied to depuration. Seawater is exposed to UV light in either a single flow-through passage or in a recirculating system before use (Blogoslawski and Stewart, 1983).

UV treatment works efficiently if seawater is first filtered to remove particulates down to 20 um as suspended material can prevent penetration of UV light. UV penetration is directly dependant on water depth and turbidity. Gametes produced

during shellfish spawning may similarly reduce UV penetration in seawater, lowering sterilization efficiency. **Should shellfish spawn during the depuration process, tanks should be immediately drained and the process begun again** (Howell and Howell, 1989). Commercial UV treatment system manufacturers limit the water depth and volume capacity of sterilizers in order to produce 99.9 % efficiency. High flow rates are limited by this restriction although several units could easily be operated in parallel. Cleanliness of the UV source is important to efficiency. Mechanical wipers can be installed on some UV units to remove fouling from the quartz sleeves (Huff et al., 1965). Muriatic acid can be used to remove fouling but requires that the system be shut down and the UV unit isolated to protect shellfish.

Ultraviolet sterilization is favored in many plants as it leaves no residuals which impair physiological processes, reduce depuration rates or otherwise harm shellfish (Richards, 1988). Conversely, as it does not leave a residual, large quantities of water cannot be stored and be expected to retain reduced bacterial counts (Blogoslawski and Stewart, 1983). UV depuration is usually effective as long as turbidity is low, flow rates are appropriate, UV lamps are operating efficiently, and the system is regularly cleaned (Richards, 1988). UV lamps should be replaced annually as the bulbs lose their effectiveness over time. DFO regulations require the installation of a UV light meter to monitor the decrease in emmission.

Behrick Enterprises Inc. (4215-24th Ave, Vernon, B.C. V1T 1M1 Phone 549-1497, Fax 549-7272), produces CSA approved, seawater rated UV units for aquaculture (including those in use by the depuration plant in Sooke). The line of products includes sterilizers with capacities from 9 to 368 US gallons per minute. The

1120-R is rated at 176 gpm and costs $7,000 complete with monitor (applicable taxes extra). The life of the 12 lamps in these units would be about 9000 hours each, and are replaced for about $900. They draw 500 watts at 120 volts. The UV unit must be located in the control room so that there is sufficient room to allow the lamps to be removed easily for cleaning and replacement.

2.6.4 Ozone

Ozone gas is very effective as a sterilizing agent in depuration systems. Ozonation is widely used in France and Australia, but because residual levels of ozone are toxic to shellfish, the method has not been popular in North America. The U.S. Food and Drug Administration regards the use of ozone in depuration as a food additive and as such it has not been cleared for use in human food. Treated water must be aerated vigorously before use and residual levels of ozone must be monitored.

2.6.5 Ultra-violet Generated Ozone

The UV lamps described above (Section 2.6.3) emit radiation at a wavelength of approximately 254 nm. Recently new lamps have become available which emit light at wavelengths in the vicinity of 180 nm. Photo-oxidation at this wavelength produces ionized gas comprised of a variety of activated oxygen radicals in addition to ozone. This highly reactive gas, often called "activated oxygen", rapidly oxidizes nitrites and other dissolved organic matter, reducing biological and chemical oxygen demands as well as turbidity, and increasing dissolved oxygen (Richards, 1988). Applications to

depuration are currently under evaluation in the United States and elsewhere.

2.7 Process Water Quality and Monitoring-

DFO has provided the following guidelines: dissolved oxygen, not less than 50% saturation (5.0 mg/L minimum); temperature will be that of the source water, but should be maintained between 2 °C and 25 °C; salinity, $\pm$ 20 % of the median salinity of the harvest site; turbidity, maximum of 25 Jackson Turbidity Units (JTU); pH, 7.0 to 8.4 units. In recirculating systems, pH may be greatly reduced by feces and other excretory products. A minimum flow rate of 5 L/min/25 kg (1 gpm/50 lbs) of live shellstock is recommended. Tank flow rates must be measured with a chart recording system to ensure adequate rates and provide evidence of sufficient flow and length of the effective depuration period to the Department of Fisheries and Oceans.

In addition to the physical and chemical water quality requirements described above, bacteriological monitoring of the depuration process water is required. Treated seawater used for purification must maintain maximum total coliform levels of $\leq$2 MPN/100 ml at all times.

Temperature, salinity, pH and dissolved oxygen measurements are most conveniently monitored with self-contained portable meters. (e.g. Yellow Springs Instruments - Fisher Scientific Limited, 196 West Third Avenue, Vancouver, B.C.). Salinity is also easily measured with a temperature compensated salinity refractometer (e.g. I.T.M. Instruments Inc., 5715 Kennedy Road, Mississauga, Ontario L42 2G4). Turbidity measurement kits are also available from Fisher Scientific.

These instruments should be calibrated on a routine basis against known standards. In the case of dissolved oxygen, the meter must be verified periodically with the Winkler method of oxygen determination,[1] and special attention should be given to the manufacturers instructions for cleaning and maintenance of the instrument. Thermometers, refractometers and turbidity kits normally need not be calibrated, excepting if they are dropped or otherwise damaged.

2.8 Depuration Tank Design and Loading-

DFO standards (Appendix A) require that tanks be constructed of inert impervious material- fiberglass is most popular- to facilitate cleaning and maintain sanitation. There must be uniform seawater flow through the baskets containing shellfish to ensure all shellfish receive the same quantity and quality of treated water. Tanks must permit proper distribution of trays or baskets without causing dead spots in seawater flow. Current patterns and mixing profiles within the operating system may be observed by following the movement of a non-toxic dye such as fluorescein. Eddies within the tanks must be eliminated as they will entrain the purged contaminants and may lead to recontamination of some shellfish. Dead spots and eddies are likely to result in localized deviations from prescribed oxygen and pH levels. Tanks must be stable and constructed of material heavy enough to prevent vibrations or disturbances which may hinder shellfish activity.

The above requirements for flow homogeneity seem to best be met by tanks that have a maximum length: width ratio of 4:1 and a maximum depth of 1 meter, accommodating no more than four basket layers. Minimum spacing between baskets

[1] Dissolved oxygen meters may require periodic calibration in air and adjustment for salinity level of the water being monitored.

and between baskets and all tank surfaces must be 8 cm or more. A rack system within the tank can easily maintain the appropriate spacing. An alternative is to provide trays with integral supports or legs (Canzonier, 1982). A minimum slope on the tank bottom of 2 cm/ meter will permit easy draining and cleaning. Tank bottoms need not be sloped themselves if the depuration room floor is properly sloped when poured.

DFO regulations also specify minimum process seawater volume for shellfish during tank operation. Littleneck clams (native and manila) and soft shell clams must have a tank volume of at least 0.15 cubic meters per 25 kg (5 cu. ft/ 50 lbs). Oysters and hard shell clams must have a minimum tank volume of 0.25 cubic meters of water per 25 kg (8 cu.ft/50 lbs). Baskets or trays may be loaded to a maximum depth of 8 cm (3 inches) for oysters and hard shelled clams and 20 cm (8 inches) for soft shelled clams (see Section 1.2).

A simple tank design of practical size (Figure 7) may be equipped with a header/aeration bar (Figure 8). It is generally more practical to operate a number of smaller tanks than fewer large tanks. If a small batch or tank load fails to depurate properly, less product, time, effort, and money will be lost than if a very large tank load fails. Tanks should incorporate a large drain to allow rapid draining and cleaning. Rapid draining rate will reduce the down time between depuration cycles. Overflow plumbing can be installed at the appropriate level, or the overflow can spill evenly over the lower end of the tank, removing much of the floating debris which normally accumulates.

Figure 8 Commercial Depuration Tank Design

(From Howell and Howell, 1989)

Tanks Specifications and Stopper Design.

(scale 1/2" = 1')

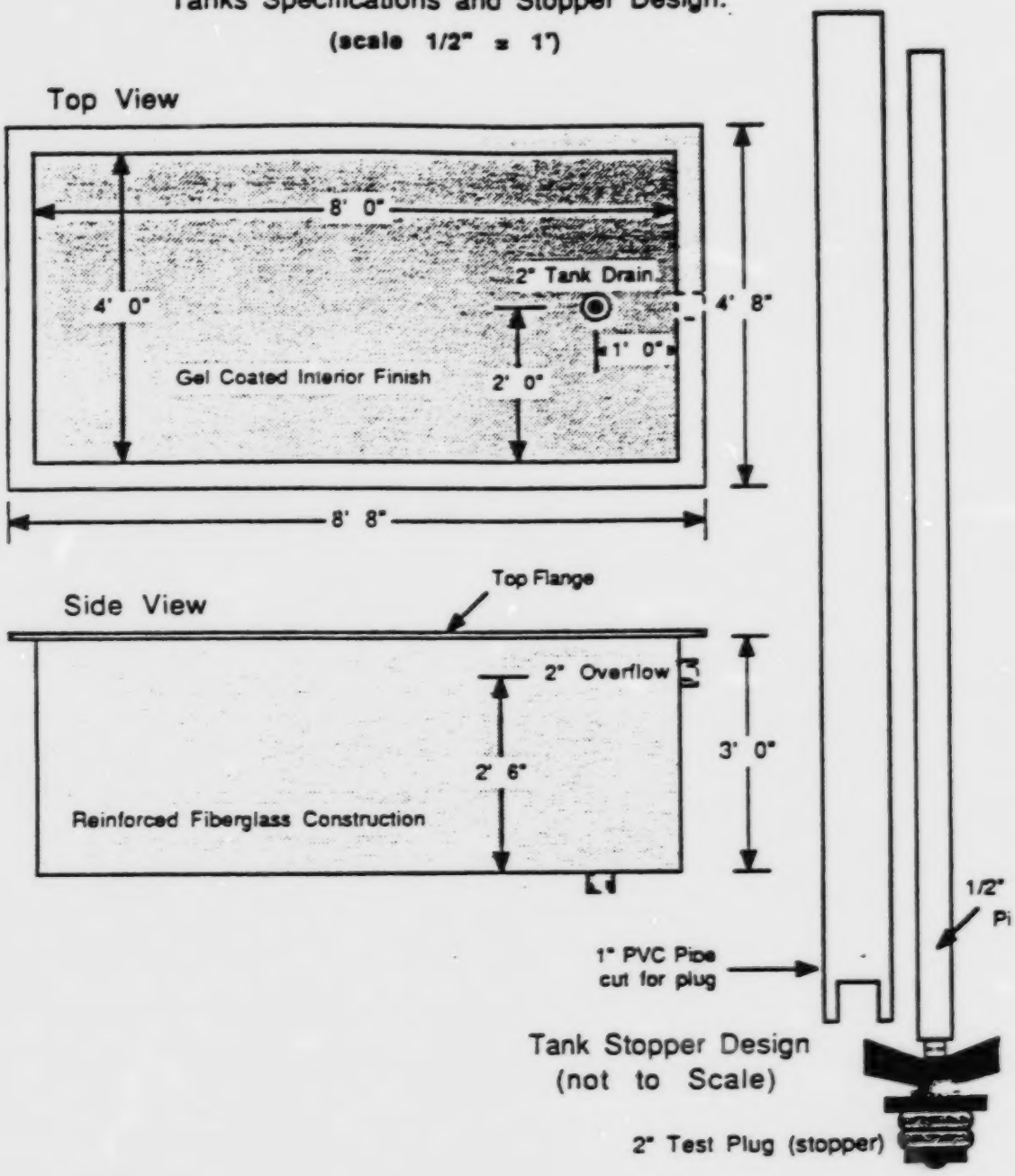
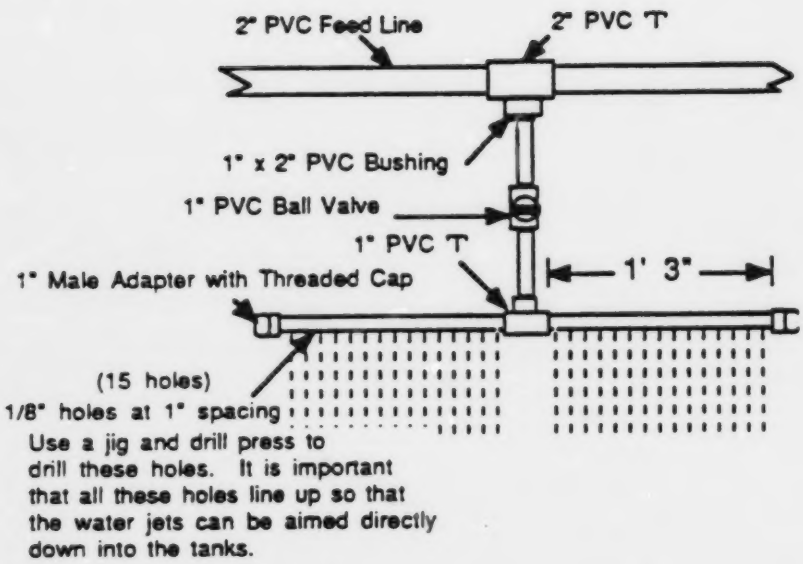


Figure 9 Aeration/Header Bar

(From Howell and Howell, 1989)


2" PVC Feed Line
2" PVC 'T'
1" x 2" PVC Bushing
1" PVC Ball Valve
1" PVC 'T'
1' 3"
1" Male Adapter with Threaded Cap
(15 holes)
1/8" holes at 1" spacing
Use a jig and drill press to drill these holes. It is important that all these holes line up so that the water jets can be aimed directly down into the tanks.

2.9 Flow Regulation-

DFO regulations require that flow regulation to depuration tanks be integrated with recording equipment to provide evidence the shellfish have received an adequate quantity of water for the appropriate period of time. Commercially available alternatives range from "flow ells" or Pitot tubes connected with chart recorders to "paddle-wheel" flow sensors which feed flow data (as well as temperature, salinity, and oxygen concentration, if desired) into computer data loggers. These are expensive (up to roughly $10,000 for the "state of the art" equipment), but available from many equipment companies. A simple alternative, in place at the Cooper's Cove facility, operates on the principle that maintaining a constant head of water in a storage tank will provide a constant flow of water through pipe(s) feeding the tank(s). The constant head tank is equipped with a float supporting a bi-metallic rod. When the tank is full and maintaining the constant head of water, the position of the rod is detected by an electromagnetic proximity switch. Deviations in head, and consequently flow to the depuration tank(s), are conveyed to the chart recorder. Flow to individual tanks can be measured by the volume of water discharged by the feeder line per unit time. In implementing this solution in monitoring water flow, the size of the "constant head" tank must be kept to a minimum as the storage of UV-sterilized water is not permitted in depuration systems. Charts must be maintained with the lot records as required by Inspection Regulations.

2.10 Product Handling Equipment-

Shellfish handling equipment includes depuration trays or baskets, washing/culling equipment, graders, scales and shellfish counters. Baskets should be easily cleanable and permit proper circulation to the contained shellfish. These criteria are satisfied by a wide variety of injection molded plastic products available from a number of fabricators in Vancouver. Howell and Howell (1989) recommend Nestier Chill Trays which can be efficiently stacked, allowing for the required spacing between the baskets, in six stacks of four baskets each in the tanks shown in figure 8. Twenty-four trays are required per tank; a minimum of one hundred and forty-four trays are required to fill the six tank system described. Nestier Chill Trays may be obtained by contacting the Nestier Corporation, 10605 Chester Road, Cincinnati, Ohio 45215. Since the cost per tray is relatively high ($25.00 each), the possibility that a local plastics injection molding service could provide a facsimile should be investigated. A complete complement of spare baskets will minimize delays between depuration cycles. Baskets should never be removed from the plant and must be used only for depuration.

As washing and culling of shellfish are required at several stages in the operation procedure a washing/culling machine or table will be necessary. Models are commercially available or can be constructed of aluminum or stainless steel. **Wash water must meet the bacteriological standards of the process water.** Shellfish are visually culled and placed into trays destined for depuration or for sale. Scales are indispensable as most shellfish, other than whole oysters, are sold by weight and regulations require accurate records of shellfish weights/volumes

processed. Washing, culling, grading, weighing or counting, and packing should be integrated in a production line to minimize labor and effort required. A platform fitted with four heavy-duty casters (a "platform dolly") will be useful in moving product around the plant. The surface of the platform should be durable and easily cleaned (e.g. fiberglass).

3.0 OPERATION

3.1 Operating Procedures-

A summary of the product handling schedule is presented in Table 5. Some points will be briefly elaborated upon here. Shellfish arriving at the plant should immediately be assigned a lot number and stored in the receiving cooler. The lot is defined as a harvest of a single species, from a single location on a specified day, by a specified harvester or group of harvesters. A lot number should be assigned which specifies, by a digital code, the day, month, location and/or growers number and species. This lot number on a tag will remain with the lot throughout the entire process and until product reaches the consumer. A random sample of shellfish is obtained (the 0-hour sample; see "Sampling", Section 3.4). The samples are placed in plastic bags and marked as 0-hour samples together with lot number, time and date. The samples must be kept chilled to prevent multiplication of bacteria before analysis. **Coliform analysis must be done within 24 hours of collecting samples. Incoming product must not be stored in the same cooler as depurated product to avoid confusion of lots and cross-contamination. A definite physical barrier must exist between the two storage areas at all times.**

Shellfish are now ready to begin the depuration process. During washing and culling, shellfish are sprayed with pressurized treated water to remove sand, mud, grit and other surface debris. Damaged, gaping or dead individuals are discarded. The remaining shellfish are loaded into the depuration trays to the appropriate depth (Section 1.2).

TABLE 5: Summary of Shellfish Handling During Depuration

GROWING AREA

HARVEST

LOAD FOR TRANSPORT

UNLOAD AT DEPURATION PLANT, ASSIGN LOT NUMBERS AND LABEL ACCORDINGLY

0-HOUR SAMPLE

REMOVE SHELLFISH FOR WASHING AND CULLING

WASH AND CULL

LOAD INTO DEPURATION BASKETS

PLACE BASKETS INTO DEPURATION TANK(S)

DEPURATION- FIRST PHASE

CLEAN PLANT

MONITOR CONDITIONS AFTER 4 HOURS

AFTER 24 HOURS REMOVE BASKETS; DRAIN AND FLUSH DEPURATION TANK(S)

RINSE SHELLFISH TO REMOVE FECES AND DEBRIS

24-HOUR SAMPLE

PLACE BASKETS INTO DEPURATION TANK(S)

DEPURATION- SECOND PHASE

AFTER 48 HOURS REMOVE BASKETS

48-HOUR SAMPLE

REMOVE SHELLFISH FOR WASHING AND CULLING

WASH AND CULL

LOAD INTO SHIPPING CONTAINERS

PLACE IN COLD STORAGE AREA

AWAIT TEST RESULTS OF 48-HOUR SAMPLE

LOAD FOR SHIPMENT

Most UV disinfection units require a few minutes to warm up. The sand filter should be backflushed for at least 3 minutes, followed by a flow through the filter to flush out toxic hydrogen sulphide gas that often builds in stagnant seawater. When the filtered water is clear, begin filling the reservoir tank and the loaded depuration tanks. Tank drain plugs should not be inserted for the first 5 minutes or so to allow the water to rinse the tank bottom. While the tanks are filling, the aeration headers should be checked to ensure there are no blockages.

When seawater flow has been established through the depuration tanks, flow rates should be checked and adjusted as necessary. After about four hours of depuration, dissolved oxygen, temperature, salinity, pH and turbidity should be monitored and recorded. This time lag for monitoring is necessary to allow the shellfish to become active and water conditions to stabilize. **Monitoring and recording will allow accumulation of data which will aid in trouble-shooting should problems arise.** Supplemental airstone aeration, if necessary, may be provided in the resevoir tank.

After the process has begun, all areas must be completely cleaned and sanitized. **Scrupulous attention to cleanliness is mandatory. Any relaxation of this stipulation is likely to lead to cancellation of operating permits.**

Shellfish exhibit visual signs of activity which will indicate the process is proceeding properly. Clams will extend their siphons and movement of water in and out of the siphons will be observable. Oysters and mussels will gape slightly and begin pumping. Pseudofeces will begin to accumulate on the surface, and sand and

other debris expelled will settle on the tank bottom. Should spawning occur in the tanks, they should be drained and the process commenced from 0-hour.

After the first 24-hour depuration period the tanks are drained, the trays are removed, and the shellfish are sprayed with treated water to wash off debris. Tanks must be similarly cleaned. This 24-hour cleanup removes debris which may create oxygen demand and/or recontaminate shellfish. After reloading the tanks and trays to begin the final 24 hours of depuration, another sample (the 24-hour sample) should be obtained to ensure that depuration is proceeding properly. Seawater flow through the system is restored as described above.

After a minimum depuration time of 48-hours the tanks are again drained. The shellfish are washed and culled, and a 48-hour sample is obtained from each lot for coliform analysis. The remainder are packaged and tagged with the appropriate lot number and either stored in the cooler, or wet-held, depending on circumstances. Release for distribution and sale awaits the test results of the 48-hour sample.

The plant, including floors, washing and culling table, trays and tanks must completely cleaned by first rinsing with cold water, then washing with warm water and detergent, followed by liberal rinsing with cold water. Sanitization is then achieved by rinsing with a 5 ppm bleach solution and liberal rinsing with cold water thereafter. **Rinsing is important as residual chlorine will be toxic to shellfish.**

3.2 Routine Maintenance Schedule-

A routine cleaning and maintenance schedule is absolutely essential to maintain the proper operating efficiency of the depuration system. A comprehensive

maintenance schedule is summarized in Table 6.

Most of the plumbing system can be adequately cleaned by filling the reservoir tank with 5 ppm bleach/fresh water and allowing the solution to flow through the aeration headers and into the depuration tanks. Tanks themselves should be scrubbed with a stiff bristle brush. More difficult areas of plumbing may be cleaned by removing clean-out plugs scrubbing the interior of the pipes with a nylon brush mounted on a plumbers snake. **Bleach is toxic to shellfish; all areas, tanks, baskets, and equipment must be well rinsed after cleaning with bleach.**

3.3 Troubleshooting-

Healthy shellfish will usually purge themselves of bacteria even under a fairly broad range of water quality conditions. However, there are a number of biological and chemical factors which will hamper their physiological activity and reduce the efficiency of the depuration process, resulting in batch failures. **Proper records of dissolved oxygen, temperature, turbidity, pH, salinity, and biological activity of the shellfish in the system will target most failures. Aside from these parameters, noxious agents such as hydrogen sulphide from stagnant seawater, or chlorine residues may be responsible; only consistent and careful attention can deal with such factors.** The plant operator may not have much control over the product before it arrives for depuration. Therefore, the degree to which the animals have been stressed, either physically or by disease, can not be fully known. This

TABLE 6:

Depuration Plant Maintenance Schedule

(for a UV-based system; adapted from Howell and Howell, 1989)

Maintenance Task	Maintenance Frequency				
	By Lot	Weekly	Monthly	Bimonthly	Yearly
Inspect UV Sterilizers	X				
Clean Quartz Tubes[1]		X			
Inspect UV Bulbs				X	
Replace UV Bulbs[2]					X
Check Tank Flow and Meter	X				
Clean Flow Meter			X		
Calibrate Tank Flow Supply				X	
Service Pumps					X
Clean Depuration Tanks	X				
Clean Circulation Plumbing			X		
Bleach Circulation Plumbing		X			
Backflush Sand Filter	X				
Replace Sand Filter Media					X
Wash and Disinfect Coolers	X				
Dispose of Waste Shellfish	X				
Wash Floors	X				
Clean Restroom[3]	(X)				
Wash Trays	X				
Wash Culling Table	X				
Lubricate Washer/Conveyor			X		
Clean Laboratory	X				
Dispose of Garbage[4]	(X)				
Painting					X
Test Fresh Water Supply					X

1. Depending on water quality.
2. Dictated by the monitor on the sterilization unit.
3. Restrooms should be cleaned daily.
4. Garbage should be removed from the plant on a daily basis.

problem can only be addressed by assessing the animals' "happiness" (physiological well-being) asbest as the operator's experience will allow.

Laboratory facilities greatly enhance the operator's ability to monitor depuration efficiency. The lab facility at the Spinney Creek Plant is presented in Figure 8. Given aseptic facilities and a little training in microbiological technique, a moderately skilled individual can measure the progress of depuration. The "elevated temperature plate count" (ETPC) using mFC media provides results on coliform numbers overnight as opposed to the standard (MPN) test used by the regulatory authorities, which returns results in three days. Both the MPN and ETPC-mFC procedures are detailed in Neufeld (1984). **Coliform assays performed at the plant should be regarded as diagnostic of plant operation only, NOT as a replacement for government tests and certification.**

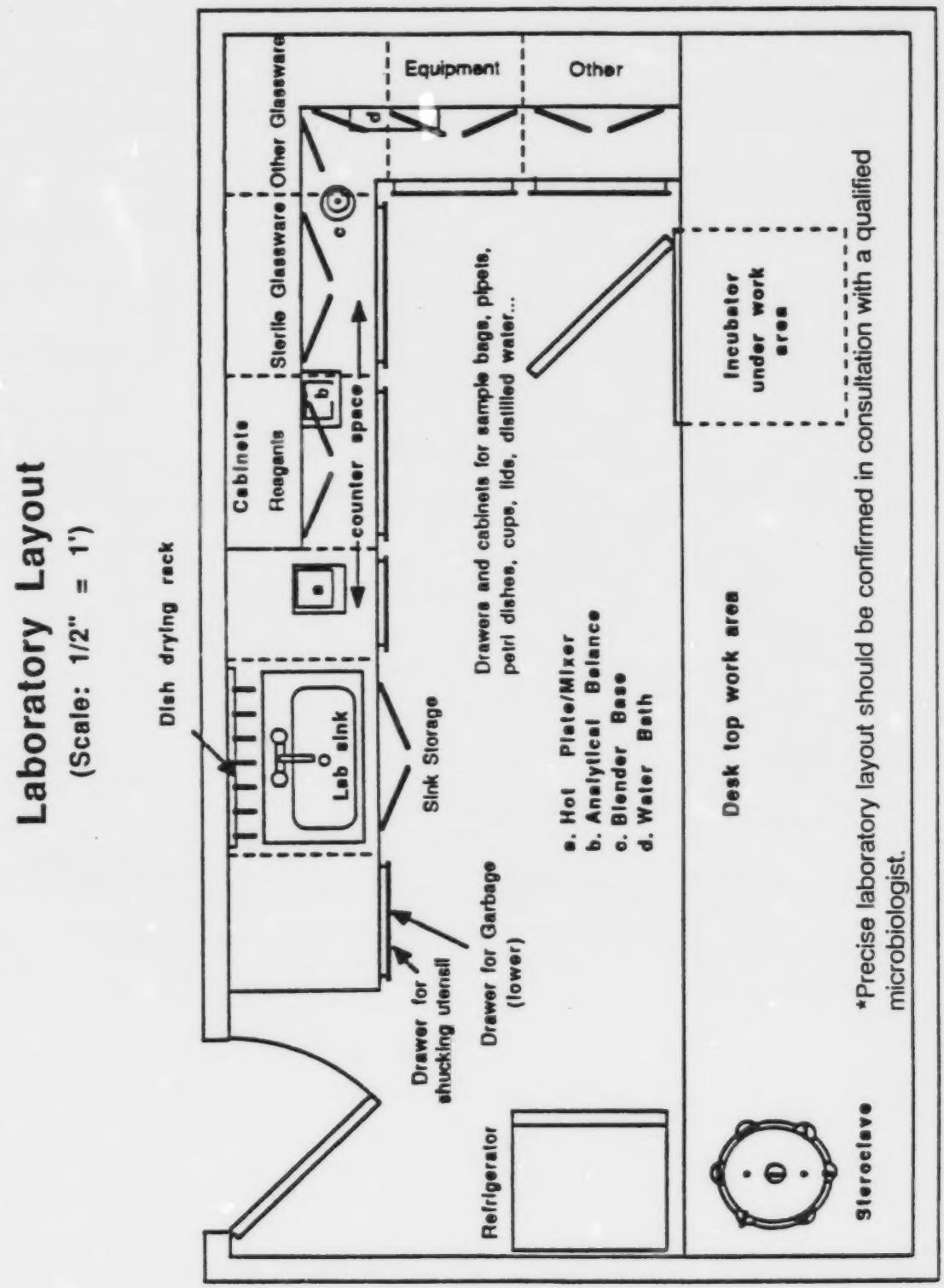
3.4 Sampling-

Individual shellfish do not depurate at the same rate, nor can it be assumed that those at different locations within a basket or tank depurate at the same rate. Individual depuration tanks may not perform at the same level of efficiency. Variation in results is inherent in the techniques used to assess bacterial loads and reduction rates. Consequently, shellfish sampling in depuration plants can be uninformative unless specific basic procedures are rigidly followed.

A single sample consists of **randomly selected shellfish from the same lot** to be analyzed by the laboratory. The number of animals comprising a sample differs with species and the "time point" at which the sample is taken. For small species,

Figure 10 Coliform Laboratory

(From Howell and Howell, 1989)



such as the Manila clam, a sample should contain 50 animals. For oysters (mediums and larger), the minimum sample size is 12 animals, maximum 50. Shellfish generally arrive at a processing plant in sacks; the 0-hour sample is obtained by taking one animal from each sack to a maximum of 50. The 24-hour (mid-depuration) sample is randomly obtained by taking single animals from different trays evenly distributed among all depuration tanks, to a maximum of 50. For example, if a lot is being depurated in 6 tanks, the 24-hour sample will consist of 8 animals from each tank, taken from the upper- and lower-most trays in each of the 4 corners of the tanks. The 48-hour (post-depuration) sample consists of a maximum of 50 animals **from each tank**, taken from trays evenly distributed within the tanks. Thus the 48-hour sample from the above-mentioned 6 tank example will consist of 6 samples of a maximum of 50 animals each.

Proper labelling and cold storage of the samples must be emphasized. In addition to lot number and date, the "time point" and, in the case of the 48-hour sample, the tank number, must also be securely afixed to the sample(s).

The Fish Inspection Branch will specify the sampling rigor required for a depuration facility. Samples are required from the harvest site prior to harvest, as well as at 0-hour, 24-hour, and 48-hours of depuration. It is in the operator's interest to maintain a rigorous sampling program at all times, to ensure minimum risk to the consumer and an adequate data base for trouble-shooting purposes. If sampling is not conducted properly, excessively contaminated shellfish may be missed and the lot rejected after the depuration process. This will result in wasted effort, production, and cost of harvesting as the shellfish must be returned to the beach or possibly destroyed

if they fail to meet process end-point criteria.

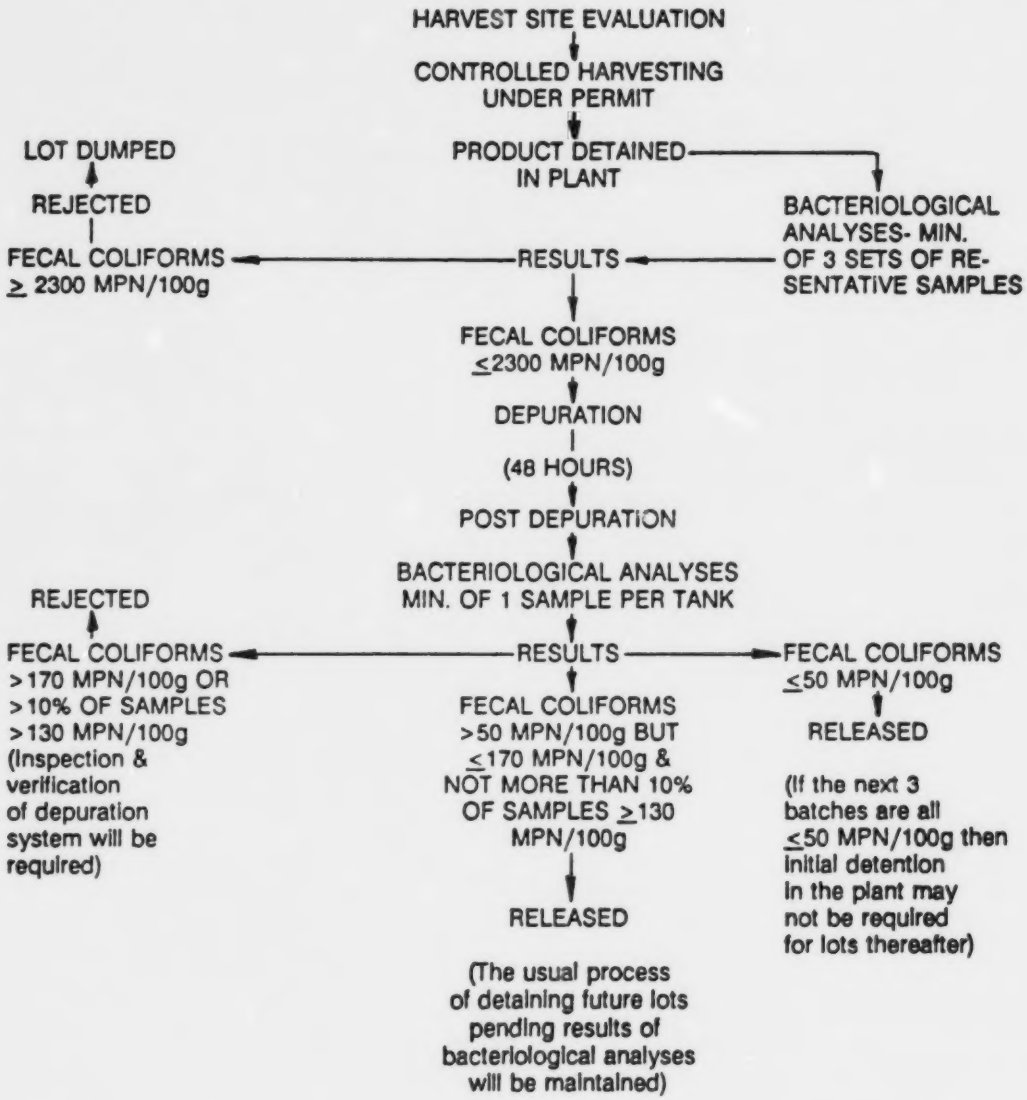
3.5 Bacteriological Criteria for Depuration-

Table 7 presents a summary of the DFO Fish Inspection Branch testing schedule (Appendix A). A key feature of these standards is the complete rejection of a harvest area if the pre-depuration sample contains coliforms in excess of 2300 (MPN). This rejection criterion may be relaxed if seawater samples fall within acceptable levels. A reduction in the sampling program may be permitted at the discretion of the Area Inspection Chief if enough bacteriological and operational data has been accumulated to demonstrate the system is consistently efficient at reducing bacterial loads. This is another strong reason for maintaining adequate records.

3.6 Record Keeping-

The prudent operator will keep the records indefinitely for assessing trends and troubleshooting. Regulations require records must be kept up-to date and retained on file by the operator at the plant for a minimum of one full year. Harvest data must include Fisheries Management Area (F.M.A.), location, date, and digger name, and tags from all sacks must be kept on file. Production records will include quantity, lot number, date, and time of initial and final depuration processing. Quality control data must include observations, comments, analytical results, and verification records. Sales records will include F.M.A., lot number and quantity, shipping date, and purchaser's name and address. Sales records will permit tracing products when necessary.

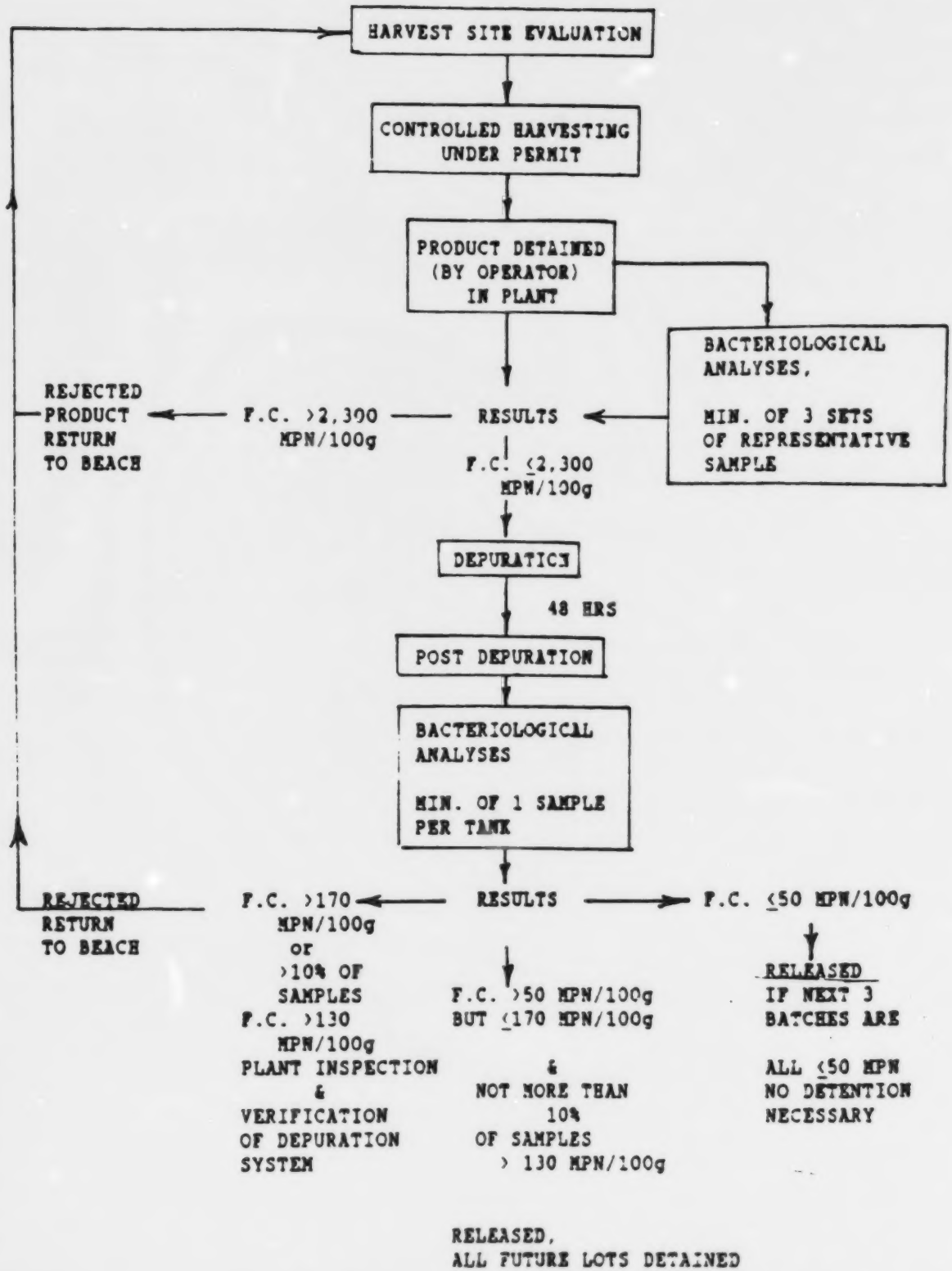
Table 7: DFO Fish Inspection Summary of Shellfish Sampling for Depuration[1]


HARVEST SITE EVALUATION
CONTROLLED HARVESTING UNDER PERMIT
PRODUCT DETAINED IN PLANT
LOT DUMPED
REJECTED
FECAL COLIFORMS ≥ 2300 MPN/100g
RESULTS
BACTERIOLOGICAL ANALYSES- MIN. OF 3 SETS OF RE-SENTATIVE SAMPLES
FECAL COLIFORMS ≤2300 MPN/100g
DEPURATION
(48 HOURS)
POST DEPURATION
BACTERIOLOGICAL ANALYSES MIN. OF 1 SAMPLE PER TANK
REJECTED
FECAL COLIFORMS >170 MPN/100g OR >10% OF SAMPLES >130 MPN/100g (Inspection & verification of depuration system will be required)
RESULTS
FECAL COLIFORMS ≤50 MPN/100g
RELEASED
(If the next 3 batches are all ≤50 MPN/100g then initial detention in the plant may not be required for lots thereafter)
FECAL COLIFORMS >50 MPN/100g BUT ≤170 MPN/100g & NOT MORE THAN 10% OF SAMPLES ≥130 MPN/100g
RELEASED
(The usual process of detaining future lots pending results of bacteriological analyses will be maintained)

1. Revised from the DFO Fish Inspection Regulations, Appendix A.

In addition to the required records, water quality data should also be maintained expressly for assessing trends and efficiency of depuration under the encountered water quality conditions.

DRAFT


HARVEST SITE EVALUATION
CONTROLLED HARVESTING UNDER PERMIT
PRODUCT DETAINED (BY OPERATOR) IN PLANT
BACTERIOLOGICAL ANALYSES, MIN. OF 3 SETS OF REPRESENTATIVE SAMPLE
RESULTS
REJECTED PRODUCT RETURN TO BEACH
F.C. >2,300 MPN/100g
F.C. ≤2,300 MPN/100g
DEPURATION
48 HRS
POST DEPURATION
BACTERIOLOGICAL ANALYSES MIN. OF 1 SAMPLE PER TANK
RESULTS
REJECTED RETURN TO BEACH
F.C. >170 MPN/100g or >10% OF SAMPLES F.C. >130 MPN/100g
PLANT INSPECTION & VERIFICATION OF DEPURATION SYSTEM
F.C. >50 MPN/100g BUT ≤170 MPN/100g & NOT MORE THAN 10% OF SAMPLES > 130 MPN/100g
F.C. ≤50 MPN/100g
RELEASED IF NEXT 3 BATCHES ARE ALL ≤50 MPN NO DETENTION NECESSARY
RELEASED, ALL FUTURE LOTS DETAINED

4.0 ECONOMICS

4.1 Economic Considerations-

The economic viability of a depuration facility in British Columbia is securely tied to the **availability of shellfish stocks** which are currently closed to harvest but can be rendered marketable through the process of depuration. The first requirement is the identification of these areas and their proximity to existing processing plant(s) or alternatively, sites suited to a "stand-alone" depuration facility. The next requirement is the assessment of the **sustained yields available** from these areas. This includes not only an assessment of the shellfish stocks, but also a realistic estimate of tide and weather "windows" for harvesting. The scale of a proposed depuration facility, and hence its associated capital and operating expenses, is governed by the amount of product to be processed. To minimize additional cost to the consumer (and therefore maximize marketability of the product), **a depuration plant must be operated at or near capacity at all times.** As DFO regulations stipulate that only one lot can be depurated at any one time, any given lot must be harvested in sufficient quantity to satisfy the capacity of the depuration system: smaller lots require almost the same investments in terms of capital and operation as "capacity-level" lots[2]. With sustained yield data in hand, the design of the depuration facility can be formulated through the "modular" approach presented in this manual.

The species destined for depuration is a major factor interwoven with the above considerations. **Market strength as well as market price should govern the**

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[2] Under certain circumstances, as judged on a case by case basis, the Fish Inspection Area Supervisor may permit more than one lot to be processed in the plant at any one time.

species chosen. In this regard, the Manila clam represents the best candidate for depuration in British Columbia. Prices are high and demand is strong. Furthermore, many of the areas described above might be managed to produce the sustained yields required. Finally, depuration systems can handle more Manila clams (by weight) than, for example, oysters because DFO regulations require less water volume per unit of clams in the depuration system than oysters (see Section 2.8). However, this system capacity difference between clams and oysters is reduced somewhat when depuration of smaller size classes of oysters (i.e. small and extra small) is considered.

Taken together, the above considerations will determine the location of a depuration facility and will define many of the variables in the construction and operation of that facility. In addition, figures for sustained yield will permit estimates of the cost of the product prior to depuration and gross revenues available for the depurated product. The difference should allow for defrayal of capital expenditures, operating costs, and a reasonable profit margin. If it does not, the proposition is not likely to be viable.

During the survey of B.C. shellfish growers and processors, it was pointed out on a number of occasions that policy would be better directed to maintaining clean, non-polluted growing areas, rather than developing ways of treating the results of pollution. This comment came particularly from oyster growers, the majority of whom have no experience with Schedule 1 closures because they have located their operations in relatively pristine areas. In areas where fecal contamination does become a seasonal problem, usually in the fall, growers either relay or delay harvest until coliform levels reduce. As the following cost estimates will show, the construction

and operation of a depuration facility solely to fullfill seasonal requirements is not likely to be a viable proposition.

4.2 Construction Costs-

Construction costs vary widely within B.C., as do the choice of building materials available. The module plans attached specify walls of concrete blocks, which are recommended by DFO as being the best and longest lasting available. The size of the building for a six tank facility (a single Spinney Creek module) has a square footage (on the ground) of 1440 sq. ft. Based on the costs of a couple of recent constructions conforming to DFO's requirements for processing plants, we have estimated that such a building can be built for $110 per sq. ft. (in 1990 dollars). This figure includes refrigeration equipment, all services (water, electrical, sewage disposal), and all engineering and consulting fees. A list of additional equipment and facilities providing "depuration services" for a single six tank module is given in Table 8. These costs are extended and summarized for the larger scale (multiple module) formats in Table 9. Note that lab facilities, included in "depuration services", are not included in the cost breakdown for a single six tank system, as the cost is not warranted (see Section 4.3).

Many will regard these cost estimates as being excessive. Indeed, there may be many ways to reduce costs. One of the most obvious ways is to add the depuration facility to an existing processing plant. Others include the "build it yourself" approach" and careful shopping for building materials and equipment. However, the figures presented here are based on the premise that it would be unwise to consider

TABLE 8: Elements and Costs of Depuration Services

6 Fiberglass purification tanks (4'X8'X3')	6,000
Sand filter with backflushing valve	1,200
Resevoir Tank	1,500
UV Sterilization unit, 180 gpm, with monitor	9,800
Recirculation pump, 1 hp, 220 V	650
Main supply pump, 2 hp, 220 V*	900
Schedule 80 PVC pipe, intake, & fittings*	6,500
Flow monitoring and recording	2,000
pH, salinity, O_2 monitoring	1,500
Labour to assemble module	6,000
Depuration trays (Nestier)	3,600
Washing and culling table	2,000
Laboratory equipment and supplies	7,000
Total Cost (1990$)	**$48,650**

Costs marked with an "*" may be signifgicantly altered by the site chosen for the plant.

TABLE 9: Extended Costs of Multiple Module Formats

MODULAR SIZE	CAPACITY[1] lbs/wk	BUILDING (sq. ft.)	BUILDING COST	DEPURATION SERVICES	LABORATORY FACILITIES	TOTAL COST[2]
1	10,000	1440	158,400	41,650	N/A	200,050
2	20,000	1920	211,200	79,130	7,000	297,330
4	40,000	3240	356,400	154,090	8,400	518,890
6	60,000	4900	539,000	213,680	9,800	762,475

1. Based on the depuration of Manila clams

2. In 1990 dollars.

such a venture without realistic estimates as a guide.

4.3 Operating Costs-

Labour is the most important operating cost of a depuration facility. The availability of a labour force to fullfill the sustained yield requirements of a depuration plant is critical. In addition, a skilled, responsible, and physically fit individual must be hired to manage the facility and coordinate the activities of depuration and record keeping. If laboratory analyses are to be carried out, a person trained in the appropriate microbiological skills will also be required. Beyond these two requirements for skilled labour, the only remaining personnel requirements are in the area of product handling i.e. for washing, grading, culling etc. Depending on the scale of the operation, some of these tasks may overlap. For example, the plant manager or the microbiologist may be required to fullfill some product handling duties as well.

Under circumstances where the proposed depuration facility is to be annexed to an existing processing plant, a portion of the labour required is not extra, as product is normally sorted and graded prior to sale. However, much of the subsequent labour inputs add extra production costs. It must also be remembered that the maximum tray densities, and the demands of cleaning at the 24 hour point will make depuration very labour intensive. If any scale of operation is contemplated attention will have to be paid to methods of transferring shell stock from the grading/cleaning area to the tanks and back to the cooler at the finish of the cycle. It is not anticipated that specialized staff would be added to the operation to handle depuration plant tasks except in larger facilities (two module format or larger). It must

be remembered that a depuration plant requires high standards of operation, so special extra demands will be placed on management.

At the operational level, the inclusion of laboratory facilities in a depuration plant deserves some special considerations. It makes good sense for the plant manager to be able to evaluate the progress of depuration of any given lot so that problems may be identified and resolved with minimum loss of product and down-time. However, the extra expense is significant and is not warranted until larger scales of operation are achieved. At lower scales the plant manager will have to rely on Government and private labs for coliform analyses. For example, a single module (six tank) plant can depurate two lots per week (@5000 lbs each or 10,000 lbs per week). For each lot, pooled samples are required for the 0-hour and 24-hour samples, and separate samples are required from each tank at the end of depuration. Therefore, eight samples are required per lot or 16 per week. A plant operating 40 weeks per year can expect to pay for the analysis of 640 samples. At current rates of $20.00 per sample, this is an expense of $12,800 per year. While this figure may as much as double with the addition of sample transportation charges (using courier services), the total does not justify hiring a microbiological technician at $30,000 per year and providing that person with analytical materials ($2000 per year). The decision not to carry out in-plant coliform analyses could only be reversed if sample transportation costs were extreme and the turn-around time for data resulted in a significant slow-down in plant production.

TABLE 10: Extended Operating Costs of Multiple Module Formats

MODULAR SIZE	CAPACITY lbs/yr[1]	LABOUR Manag.	LABOUR Gen.	LABOUR Micro.	MAIN. & REPAIR[2]	SERVICES (hydro etc)	LAB. SUP.	BANK PAY.[3]	TOTAL COST	COST PER POUND ($)
1	400,000	30,000	15,000	20,000[4]	3,000	2,000	N/A	24,000	89,000	0.22
2	800,000	35,000	30,000	30,000	6,000	4,000	3,000	36,000	134,000	0.17
4	1,600,000	40,000	60,000	35,000	12,000	8,000	6,000	60,000	201,000	0.13
6	2,400,000	45,000	90,000	35,000	18,000	12,000	9,000	96,000	275,000	0.11

1. Based on a 40 week operating year and the Manila clam as the species being depurated.
2. Includes contingency allowances.
3. Estimated on the basis of a 25 year mortgage in which the total payout is 3 times the amount borrowed. It is assumed that the entire capital cost of the facility is borrowed.
4. This is an allowance for coliform analyses by private labs rather than for on-site personel.

Table 10 shows a breakdown of estimated annual operating costs for four scales of depuration facility presented in this manual, based on a production year of 40 weeks. These costs are extended to an estimate of the cost per pound of depurating Manila clams. At current prices (to the digger), the smallest scale facility would add about 10% to the cost of this product. If oysters are considered instead, making allowances only for the reduced capacity of the system to depurate oysters (see Section 4.1, above), not for any size class considerations, then the price per pound becomes $0.36, $0.28, $0.21, and $0.19 for the 1, 2, 4, and 6 module systems, respectively. Clearly, as oysters are marketed by the dozen, the depuration of small size classes is favoured. The costs of depurating shucking stock would appear to be prohibitive.

BIBLIOGRAPHY

Allen, L.A., G. Thomas, M.C.C. Thomas, A.B. Wheatland, H.N. Thomas, E.E. Jones, and J, Hudson. 1950. Repeated re-use of seawater as a medium for the functioning and self-cleansing of molluscan shellfish. Journal of Hygiene 48(4): 431-457.

Barrow, G.I., and D.C. Miller. 1969. Marine bacteria in oysters purified for human consumption. Lancet 2:421-423.

Belding , D.L., and F.C. Lane. 1909. The shellfisheries of Massachusetts: their present condition and extent. pp. 16-233. In: A report upon the mollusk fisheries of Massachusetts. Wright and Potter Printing Co., State Printers, Boston.

Bernard, J. 1987. Ozone + ultra-violet water treatment. Aquatech, Amsterdam, September 16-17, 1986. Ozonews 15:5.

Blogoslawski, W.J. and M.E. Stewart. 1983. Depuration and Public Health. J. World Maricul. Soc. 14: 535-545.

Buisson, D.H., G.C. Fletcher, and C.W. Begg. 1981. Bacterial depuration of the Pacific oyster (Crassostrea gigas) in New Zealand. N. Z. J. Sci. 24:253-262.

Canzonier, W.J. 1982. Depuration of bivalve mollusks -what it can and cannot accomplish and some practical aspects of plant design and operation. Proc. International Seminar on Management of Shellfish Resources. Irish Mar. Farmers Assoc., Tralee, Ireland.

Canzonier, W.J. 1984. Technical aspects of bivalve depuration plant operation: pipes, pumps and petri plates. pp. 68-96. In; A.J. O'Sullivan (ed), Mussel Bound. Proc. Int'l Shellfish Seminar, Environmental Management Services. Bantry, Ireland.

Carmelia, F.A. 1921. Hypochlorite process of oyster purification. Publ. Health Series Rep. pp. 876-883.

Casali, P., M.C. Marcucci, and W.J. Canzonier. 1981. Depuration of the clam, Venus gallina, in a commercial plant. L'Igiene Moderna 75:669-692.

Chang, J.C.H., S.F. Orsoff, D.C. Lobe, M.H. Dorfman, C.M. Dumais, R.G. Qualls, and J.B. Johnson. 1985. UV inactivation of pathogenic and indicator microorganisms. Appl. Environ. Microbiol. 49: 1361-1365.

Davis, C. 1964. The influence of suspensions of microorganisms of different concentrations on the pumping and retention of food by the mussel (Mytilus edulis L.). Neth. J. Sea Res. 2:233-249.

Department of Fisheries and Oceans. 1988. 1988/1989 British Columbia tidal waters sport fishing guide. Minister of Supply and Services, Ottawa. DFO/4075. pp. 45-71.

Devlin, I.H. 1973. Operation report: Oyster depuration plant- Ladysmith, B.C. Environment Canada, Vancouver, B.C. 108 pp.

Devlin, I.H. and N. Neufeld. 1971. Oyster depuration plant, Ladysmith, B.C.: Final report. Inspection Branch, Fisheries Service, Dept. of the Environment, Vancouver, B.C. 28 pp.+5 App.

Dodgson, R.W. 1928. Report on mussel purification. Ministry of Agriculture and Fisheries. Fishery Invest. Series II 10:1-436.

Dodgson, R.W. 1936. Shellfish and the public health. Brit. Med. J. pp. 169-173.

Fabre-Domergue, M. 1912. Bacterial purification of oysters standing in filtered artificial seawater. Compt. Rend. Acad. Sci. 154:393-395.

Fleet, G.H. 1978. Oyster depuration - a review. Food Technol. Aust. 30: 444-454.

Fogh, J. 1955. Ultraviolet light inactivation of poliomyelitis virus. Proc. Soc. Exp. Biol. Med. 89:464-465.

Furfari, S.A. 1966. Depuration plant design. Public Health Service Pub. No. 999-FP-7. U.S. Dept. Health, Education, and Welfare, Washington, DC. 119 pp.

Furfari, S.A. 1976. Shellfish purification: A review of current technology. FAO Tech. Conf. on Aquaculture, Publ. FIR:AQ/Conf/76/R.11. Kyoto, Japan. 16 pp.

Furfari, S.A. 1982. Current Shellfish Purification Practices. U.S. Department of Health and Human Services, Food and Drug Administration, Shellfish Sanitation Branch.

Galtsoff, P.S. 1946. Reaction of oysters to chlorination. U.S. Fish Wildlife Serv. Res. Rept. 11, U.S. Government Printing Office, Washington, D.C.

Hedstrom, C.E., and E. Lycke. 1964. An experimental study on oysters as virus carriers. American Journal of Hygiene 79:134-142. In: Blogoslawski, W.J. and M.E. Stewart. 1983. Depuration and Public Health. J. World Maricul. Soc. 14:535-545.

Herdman, W.A., and R. Boyce. 1899. Oysters and disease. An account of certain observations upon the normal and pathological histology and bacteriology of the oyster and other shellfish. Lancashire Sea-Fisheries Memoir No.1. London, pp. 35-40.

Hickman, C.P. Sr., C.P. Hickman, Jr., F.M. Hickman and L.S. Roberts. 1979. Integrated Principles of Zoology, 6th Ed. C.V. Mosby Co., St. Louis, Missouri.

Hill, W.F., Jr., F.E. Hamblet, W.H. Benton. and E.W. Akin. 1970. Ultraviolet devitalization of eight selected enteric virusus in estuarine water. Appl. Microbiol. 19: 805-812.

Hoar, W.S. 1983. General and comparative physiology. 3rd ed. Prentice-Hall, Inc., Englewood Cliffs, New Jersey. 851 pp.

Honn, K.V. and W. Chavin. 1976. Utility of ozone treatment in the maintenance of water quality in a closed marine system. Marine Biology 34:201-209.

Houser, L.S. 1964. Depuration of shellfish. J. Environ. Health 27:477-481.

Howell, T.L., and L.R. Howell. 1989. The controlled purification manual. New England Fisheries Development Association, Inc.Boston, Massachusetts. 77 pp.

Huff, C.B., H.F. Smith, W.D. Boring, and N.A. Clarke. 1965. Study of ultraviolet disinfection of water and factors in treatment efficiency. Public Health Reports 80:695-705.

Huguenin, J.E. and J. Colt. 1989. Design and Operating Guide for Aquaculture Seawater Systems. Developments in Aquaculture and Fisheries Science 20. Elsevier, New York. 264 pp.

Ingersoll, E. 1881. The history and present condition of the fishery industries. The oyster-industry. Tenth Census of the United States. Dept. of the Interior, 124 pp.

Johnstone, J. 1908. Bacteriological investigations in relation to shellfish pollution. Lancashire Sea-Fisheries Lab. Rept. No.17. In Richards G.P. 1988. Microbial purification of shellfish: A review of depuration and relaying. J. Food Prot. 51:218-251.

Johnstone, A. 1914. The methods of cleansing living mussels from ingested sewage bacteria. Lancashire Sea-Fisheries Lab. Rept. No. 23, pp. 57-108.

Kelly, C.B. 1961. Accumulation of bacteria by the Pacific and Olympic oysters. Shellfish Sanitation Research Conference, Purdy, WA. 8 pp. (Unpublished). In:

Richards, G.P. 1988. Microbial purification of shellfish: A review of depuration and relaying. J. Food Prot. 51:218-251.

Kelly, M.T., and A. Dinuzzo. 1985. Uptake and clearance of Vibrio vulnificus from Gulf Coast oysters (Crassostrea virginica). Appl. Environ. Microbiol. 50:1548-1549.

Ledo, A., E. Gonzalez, J.L. Barja, and A.E. Toranzo. 1983. Effect of depuration systems on the reduction of bacteriological indicators in cultured mussels (Mytilus edulis Linnaeus). J. Shellfish Res. 3:59-64.

Marcucci, M.C., P.Casali, L. DaRos, and W.J. Canzonier. 1980. Rapid and sensitive method for monitoring the depuration of bivalve molluscs. L'Igiene Moderna 74:393-402.

Marvel, P. 1902. Report of the New Jersey State Board of Health. In: Richards, G.P. 1988. Microbial purification of shellfish: A review of depuration and relaying. J. Food Prot. 51:218-251.

Neilson, B.J., D.S. Haven, F.O. Perkins, R. Morales-Alamo, and M.W. Rhodes. 1978. Bacterial depuration by the American oyster (Crassostrea virginica) under controlled conditions. Vol. 2. Practical considerations and plant design. Special Scientific Report No. 88. Virginia Institute of Marine Science, Gloucester Point, VA. 48 pp.

Neufeld, N., A. Tremblett, and K. Jackson. 1975. Clam depuration project. Inspection Branch, Fisheries Service, Environment Canada, Vancouver, B.C. 35 pp.

Neufeld, N. 1984. In: Greenberg, A.E., and D.A. Hunt. Eds. 1985. Laboratory procedures for the examination of seawater and shellfish. 5th ed. American Public Health Association, Washington. pp. 37-54.

Phelps, E.B. 1911. Some experiments upon the removal of oysters from polluted to unpolluted waters. J. Am. Pub. Health Assoc. 1:305-308.

Quadri, R.B., K.A. Buckle, and R.A. Edwards. 1986. Reduction in sewage contamination in Sydney rock oysters. Food Technol. Aust. 28:411-416.

Quayle, D.B., and F.R. Bernard. 1976. Purification of basket held Pacific oysters in the natural environment. Proc. Natl. Shellfish Assoc. 66. 69-75.

Richards, G.P. 1985. Outbreaks of shellfish-associated enteric virus illness in the United States: Requisite for development of viral guidelines. J. Food Prot.48:815-823.

Richards, G.P. 1988. Microbial purification of shellfish: A review of depuration and relaying. J. Food Prot. 51:218-251.

Scotti, P.D., G.C. Fletcher, D.H. Buisson, and S. Fredericksen. 1983. Virus depuration of the Pacific oyster (Crassostrea gigas) in New Zealand. N. Z. J. Sci. 26:9-13.

Souness, R., R.G. Bowrey, and G.H. Fleet. 1979. Commercial depuration of the Sydney rock oyster, Crassostrea commercialis. Food Technology in Australia 31: 531-537.

Tohyama, Y., and Y. Yasukawa. 1936. Purification of Polluted oysters. Department of Food Control, Government Institute for Infectious diseases, Japan. In: Blogoslawski, W.J. and M.E. Stewart. 1983. Depuration and Public Health. J. World Maricul. Soc. 14: 535-545.

Violle, H. 1929. De la sterilisation de l'eau de mer par ozone: applications de cette methode poure le purification des coquillages contamines. Revue d'Hygiene et de Medecine Preventive 51:42-46. In: Blogoslawski, W.J. and M.E. Stewart. 1983. Depuration and Public Health. J. World Maricul. Soc. 14: 535-545.

Wells, W.F. 1928. Chlorination as a factor of safety in shellfish production. Am. J. Publ. Health. 19:72-77.

Wood, P.C. 1966. Shellfish purification- A review of current European practices. Abstr. Nat. Conf. on Depuration. Kingston, Rhode Island.

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Appendix A. Department of Fisheries and Oceans Guidelines

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9. SHELLFISH PURIFICATION

Shellfish harvested from contaminted areas impose a health hazard to the consumer. Shellfish from marginally contaminated areas may, however, cleanse themselves if they are subject to controlled purification processes.

COMPLIANCE:

No shellfish may be taken from closed areas except under the terms of a permit issued for the purpose of purification treatment as specified under a Memorandum of Understanding (MOU) between the applicant and the Department.

Prior to the issuance of any permit, the following conditions must be satisfied:

1) Harvest site acceptability,

2) Approved purification facility and method, and

3) The applicant's acceptance of responsibility for the entire process and committment to maintain control of the product from the time of harvest to the time of release.

Details on the purification program will be described in the sections that follow.

9.1. HARVEST SITE APPROVAL

Each proposed site must first be reviewed and sampled under Departmental supervision to ensure that shellfish harvested from the site will be able to cleanse itself during the purification process. Experience has shown that if the bacterial level in the shellfish is too high, normal purificatin procedures will not reduce the bacterial count to an acceptable level.

Chemicals or other toxic materials are not known to decrease under normal purification procedures. Sites where shellfish do show abnormal levels of chemicals or toxic materials shall not be approved for purification.

COMPLIANCE:

Site Evaluation Criteria:

1) Document review of existing files to determine the cause of the closure. Sanitary survey data shall not show gross pollution conditions. If an update is necessary, on-site inspection to verify the source or potential sources of contamination shall be conducted.

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2) Sanitary survey data to show that the bacteriological quality of every water sampling station in those portion of the area exposed to faecal contamination during the worst pollution conditions shall meet the following standard:

   The faecal coliform median MPN of the water not to exceed 88 per 100 ml and not more than 10 percent of the samples to exceed an MPN of 260 per 100 ml for a 5-tube decimal dilution test.

3) On-site sampling of the shellfish for bacterial and chemical contamination will be done under Inspection supervision. Separate samples will be taken at different locations on the beach and at various intertidal levels. The samples will be analyzed individually for bacteriological results to obtain a comprehensive profile of the proposed site. The sample for chemical analysis may be pooled unless there is a reason to suspect non-homogeneity.

4) No shellfish tissue sample shall have a faecal coliform level of 2,300 MPN/100g. If there are any radionuclides, elevated levels of heavy metal, or toxic chemicals, the site shall be rejected.

9.2. TERMS OF A HARVEST PERMIT

Control and verification are the two key elements of a permit system. Both the applicant and the Department must maintain these two elements during the term of the permit. Failure to do so may jeopardize consumer health. If the logistics does not allow the Department to maintain an effective supervision and verification program, no harvest permit shall be issued nor any Memorandum of Understanding signed.

COMPLIANCE:

When a harvest site is found acceptable for purification purposes, the applicant shall submit a quality control plan specifying the method of harvesting, transportation, and purification. Upon acceptance of the plan and subject to operational capacity of the Department, a Memorandum of Understanding may be signed between the applicant and the Department. The applicant shall submit the name of a master digger who will supervise the digging.

A harvest permit shall specify the following:

1) - the name of the applicant, the name of the master digger if applicable,
   - the location of harvest,
   - the effective date and the expiry date,
   - the purification site.

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2) All sacks or containers of shellfish must be properly tagged on site with accurate information on the area, the location, the date, and the name of the digger. In cases where oysters from a single lease or location are delivered in bulk, individual tags can be substituted by a statement signed by the master digger or the permit holder.

3) All shellfish must be delivered directly from the harvest site to purification site under supervision.

4) At the time of harvesting, the permit holder shall erect a sign stating:

"CONTAMINATED AREA HARVESTING"
UNDER PERMIT FOR
PURIFICATION ONLY
PERMIT NO. _____

The sign shall be no less than 0.7 meter wide by 1.0 meter long, and the wordings be visible from a distance of at least 50 meters.

5) The permit holder and the master digger shall have with them, an up-to-date list of diggers showing the name and personal commercial fishing licence number of each digger.

6) Prior to each harvest trip, the permit holder shall inform the fishery officer in charge of the area.

A Memorandum of Understanding (MOU) shall have provisions for the following specifications:

1) The harvest site.

2) The purification site; either the relay site or the depuration plant.

3) The name of the master digger who will represent the applicant in supervising the harvest process on site.

4) The permit holder and the master digger shall have an up-to-date list of the diggers at the harvest site.

5) The method and procedure of gathering and transporting the shellfish from the harvest site to the purification site.

6) The actual purification process and the minimum duration of the process.

7) Quality Control Program: detailing the method and control criteria for the entire operation.

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8) Record Keeping: up-to-date, accurate and verifiable records must be kept at the plant on:

- the harvest data: area, location and date of harvest, the tags for each sack must be maintained on file;

- the production record: quantity, lot number, date and time of commencement and completion of processing;

- quality control data: observations and comments, analytical results, and record of verification;

- sales record: the area, the lot number (which will allow the product origin and the production to be traced), the lot size, the shipping date and the name and address of the purchaser.

All records must be kept on file for a minimum of one full year.

9) Subject to Release:

All shellfish harvested under the MOU must remain under detention pending release by the Department.

10) The Effective and Expiry date of the Agreement.

11) Provision to cancel the Agreement and all permits on in the event of non-compliance.

9.3 TYPES OF PURIFICATION

Purification describes the natural process of the shellfish to biologically cleanse itself when it filter feeds in sanitary water. The rate of purification is dependent on the physiological state of the shellfish and the water quality (temperature, salinity, dissolved oxygen, etc.) in which the shellfish is held.

There are two basic categories of purification:

1) Relaying - purification under natural environment.

2) Depuration (controlled purification) - purification in a controlled environment.

9.3.1 RELAYING

A process where live shellfish from a contaminated site are transferred to an approved area to allow biological self-cleansing under natural environment.

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9.3.1.1 THE RELAYING SITE

COMPLIANCE:

The site must be located in an approved area. Documentation or on-site review is recommended to ensure that there is no recognizable non-point source (e.g. boat anchorage) of pollution.

The water temperature should not be too cold (minimum of +5 degrees C) or the salinity difference too great (+ or -20%) from the harvest site. The shellfish should be submerged in sufficient depth to reduce the chances of surface contamination or the interruption of the cleansing process at low tides.

The topology of the subtidal beaches may also influence the ability of the shellfish to purify itself. Shallow basins frequently expose the shellfish during low tides thus increase the chance of surface contamination and interrupts the cleansing process.

9.3.1.2 METHODOLOGY AND EQUIPMENT

When specifying the method and the equipment used for the relaying process, consideration should be given to the following:

- Whether it is beach relaying or container relaying, the method proposed must allow for the proper cleansing of the shellfish during a specified time period.

- Trays, containers or other equipment used for holding the shellfish must be designed to maximize water circulation and allow equal exposure of all shellfish. They shall be made of inert material. Packing the shellstock in sacks will restrict water circulation and prevent unform cleansing.

- There must be provision made to allow easy recognition of lot identity.

- Adequate provision must be made for the rapid transfer of purified shellfish to the processing plant without exposure to further contamination.

9.3.2 DEPURATION (CONTROLLED PURIFICATION)

Depuration is a process of cleansing shellfish in a controlled environment. Mr. Santo Furfari has prepared a protocol on this subject as a Proposal For Addition to Part II of the (N. S.S.P.) Manual - "APPENDIX D - CONTROLLED PURIFICATION". Most of the following parameters are taken from his proposal:

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9.3.2.1 PLANT SITE

While site selection is a corporate decision, it is advisable to consider the following factors:

- Sea water quality at the site - are there any problems with silt, suspended matter, pH, salinity, or seasonal fluctuations of water temperature.

- Adequacy of potable water supply, electricity, waste disposal services or sites.

- The distance to the harvest sites and proximity to major highways or transportation systems.

- The presence of potential pollution sources such as waste treatment plants or outfalls.

- The effluent discharged should not alter the water quality of the receiving environment.

9.3.2.2 PLANT DESIGN AND CONSTRUCTION

COMPLIANCE:

In addition to meeting the constructional requirements of Schedule I, Parts I and IV of the Fish Inspection Regulations, the plant should be so designed to reduce the chances of cross contamination and the likelihood of allowing contaminated shellfish to bypass the depuration system.

Since volume and continuity of supply are the basic determinants of economic success in a depuration operation, it is essential to have adequate storage rooms with temperature controls for holding the shellstocks. The undepurated shellstocks must not be held in the same room as the depurated product. Separate holding rooms are required.

9.3.3. DEPURATION SYSTEM:

A depuration system shall have an adequate supply of treated seawater. The system must be designed to allow all shellfish to receive the same quantity and quality of the treated seawater.

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9.3.3.1 SEAWATER QUALITY

COMPLIANCE:

- Bacteriological compliance: Total Coliform ≤2 MPN/100 ml.
- pH at 7.0 to 8.4
- Salinity: Within + or -20% of the salinity of the harvest area (in parts per thousand).
- Dissolved oxygen: minimum level of 5.0 mg/liter (i.e. 5.0 ppm).
- Chemical: free from unacceptable levels of trace metals, organic contaminants or toxic material that would inhibit the physiological activity of the shellstock or would otherwise constitute a health hazard to the consumer.
- Temperature: must be within the range where the shellfish will pump actively.

9.3.3.2 SEAWATER INTAKE SYSTEM:

The system design and the pipe size will vary depending on the needs of the plant. The intake pipe should not be located in close proximity to the discharge pipe. Piping material must be non-toxic, inert and non-corrodible. The pipe size should be sufficiently large to provide an adequate supply of seawater to the plant. Past experience has suggested a flow rate of 5 litres per minute for each 25 kg (1.0 gallon per minute for each 50 lbs.) of hardshell clams or oysters. A flow meter equipped with a continuous recorder must be installed at a strategic location along the water line to measure the flow rate.

9.3.3.3 SEAWATER TREATMENT

- Sterilization: the most commonly used system is an ultraviolet light irradiation unit with an automatic water shut-off if the U.V. radiation is not detected by the photo sensor. Continuous sterilization is mandatory in order to ensure that intermittent pollution of the incoming seawater will not re-contaminate the product. The seawater must be treated immediately prior to entering the depuration tanks to avoid possible re-introduction of contamination.
- Filtration: water turbidity will greatly reduce the effectiveness of the U.V. treatment. A proper filtration system will remove particulates and other macroscopic material.

- Aeration: inadequate oxygen in the water will inhibit the physiological activity of the shellfish. Aeration can be achieved by spray discharging of the water or by bubbling compressed air into the tank.

- Heating: If depuration continues in the winter months when the water temperature is near the freezing point, provision to warm the water will be necessary. Heat exchangers could be used for warming the water.

9.3.4 TANK AND BASKET DESIGN:

The tanks and baskets shall be constructed of sturdy, inert and impervious material to facilitate easy cleaning. The tank and basket design must:

- assure uniform hydraulic flow throughout the system so that every shellfish will receive the same quantity and quality of water;

- allow proper stacking and removal of baskets without causing dead pockets in the hydraulic system;

- prevent vibrations or ther disturbances which might affect the activity of the shellfish.

COMPLIANCE (Guideline):

Experience has indicated that the following dimensions may be adequate:

- Rectangular tanks: maximum length to width ratio of 4 to 1.

- Depth: maximum of 1 meter (36 inches) to accommodate not more than 4 layers of baskets or containers. The minimum spacing between baskets should be at least 8 cm (3 inches) all around.

- Bottom slope: the bottom of the tank should be sloped to drain at a minimum rate of 2 cm per meter (1/4 inch per foot) to allow easy cleaning.

- Minimum process seawater capacity to overflow level:

  0.15 cubic meter per 25 kg (5 cu. ft. per 50 lbs) for soft shell clams

  0.25 cubic meter per 25 kg (8 cu. ft per 50 lbs) for hard shell clams and oysters

- Maximum depth of Shellfish in each container: 8 cm (3 inches) for oysters and hard shell clams; 20 cm (8 inches) for soft shell clams.

9.3.5 OPERATIONAL REQUIREMENTS

Good operational practices will maximize product quality and minimize product loss. Product scheduling, proper storage facilities, initial washing and culling of the shellstocks prior to depuration will help to maximize return.

Regular tank and basket clean-ups and disinfection will prevent the introduction of bacteria during the depuration process.

COMPLIANCE:

In addition to the requirements of Schedule II, Parts I and IV of the Fish Inspection Regulations, the following operational schedules must be observed:

9.3.5.1 STORAGE OF SHELLSTOCKS

Shellfish awaiting depuration must be kept cool to minimize product lost due to mortality.

Incoming shellstocks must not be stored in the same cooler as the depurated product to avoid possible cross contamination or accidental mixing of products.

9.3.5.2 WASHING AND CULLING:

The shellfish must be adequately rinsed with pressurized water to remove sand and dirt prior to depuration. Visual culling should also be conducted at the same time to remove any damaged, gaping, or dead shellstocks.

9.3.5.3 TANK CLEANUP AFTER 24 HOURS:

Each depuration tank must be cleaned and disinfected after the first 24 hours of depuration. This shall be done with the removal of all baskets from the tank. Care must be exercised to avoid re-contaminating the shellfish during loading and unloading.

9.3.5.4 MARKET PREPARATION:

The depurated shellfish must be packed in clean containers. Any broken, gaping or dead shellfish shall be removed.

9.4 SAMPLING AND BACTERIOLOGICAL CRITERIA

GENERAL RULES:

1. One Permit At A Time: Each plant is allowed to harvest in only one contaminated area at any time. This will prevent the possibility of mixing shellstocks from different locations prior to or during depuration.

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2. One Lot Per Location Per Day: For the purposes of identification, a lot shall consist of shellfish taken from the same harvest location and destined for depuration on a single day. The size of each lot shall not exceed the maximum daily capacity of the depuration system. Any excess shellfish shall be considered a different lot and subjected to regular sampling.

3. Three Consecutive Acceptable Lots: When the faecal coliform level of incoming shellfish is <50 MPN/100g for each of first three consecutive lots, the requirement of detaining each lot pending bacteriological results may be relaxed at the discretion of the Inspection Supervisor.

4. Representative Sampling: To obtain a bacteriological profile of a lot, the sample must be taken UNIFORMLY from the lot. Unlike random sampling where it is possible to take all the required units from a single sack within a lot, a representative sample should be comprised of units from a cross section of sacks.

9.4.1 SITE APPROVAL

COMPLIANCE:

The water quality must meet the standard prescribed under Section 9.1 of the manual. At least three separate samples shall be taken from each proposed harvest site. The sampling locations shall be determined by the Inspection Officer who would supervise the pre-sampling program.

If none of the samples show a faecal coliform level of >2,300 MPN/100g, the site may be approved provided that it meets all other criteria of site evaluation.

9.4.2 PRE-DEPURATION:

- A representative sample will be taken prior to depuration. This pre-depuration sample may be taken at any time as soon as a lot number has been assigned.

- If the result is ≤2,300 F.C., depuration may proceed or continue; if it is >2,300 F.C., the lot is rejected and the entire shipment must be returned to the beach. Past experience has shown that shellfish with high bacterial level will not depurate properly.

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9.4.3 POST DEPURATION:

- All shipments must be detained until the bacteriological result of the post depuration sample is found satisfactory.

- A minimum of one sample shall be taken from each tank at the end of the depuration process.

- If the result of the final product has F.C. level of:

  ≤50 MPN/100g, the lot may be released.

  >50 and ≤170 MPN/100g with less than 10% of the sample exceeding 130 MPN/100g ,the lot may be released, but all future shipments must be detained.

  any >170 MPN/100g or if 10% or more of the samples exceed 130 MPN/100g, the lot is rejected. All future shipments must be detained. Plant inspection as well as system evaluation will be conducted to ensure that there is no equipment failure.

- In the event that only one sample is taken per lot, the product shall be rejected if the level of F.C. exceeds 170 MPN/100g. All future lots will be detained and system evaluation shall be conducted. If the single sample result is greater than 50 but ≤170 MPN/100g, the sample may be accepted, but future lot will be detained.

- If the results of the post-depuration sample of three consecutive shipments from the same location are all <50 in F.C., the Inspection Supervisor may at his discretion, waive the detention requirement as outlined in Section 9.4.2.

Figure 9.2 summarizes the above criteria.

9.4.4 REDUCED SAMPLING FOR PROVEN DEPURATION SYSTEMS

At the discretion of the Area Inspection Chief, a reduced sampling scheme may be implemented if sufficient operational and bacteriological data have been accumulated to establish that the depuration system is indeed fully functional. The reduced sampling scheme should not be opted for prior to the establishment of satisfactory records performance.

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OPTIONAL REDUCED SAMPLING SCHEME:

If the F.C. level of the PRE-DEPURATION sample is:

<50	post depuration sample may not be required
>50 - ≤170	1 post depuration sample per lot is required
>170 - ≤2,300	1 " " " " tank " "
>2,300	the lot is rejected and must therefore be returned to the beach.

- No product may be removed from the depuration tanks until the pre-depuration results are known and recorded.

- Post depuration sample: The criteria are the same as those specified in Section 9.4.3.

9.4.5 SAMPLE SHIPPING

Precautions should be taken during sampling to avoid introducing any contaminants.

The shellfish shall be placed in a new, clean plastic bag which can be sealed or tied to prevent possible cross contamination. Information on the sample, such as lot number, the area and location of harvest, the sampling time and date, as well as the weight of the lot shall be recorded on a sampling form. To prevent the form from getting wet, it can be placed in a plastic bag and tied together with the sample. To help maintain the sample in a cool environment, a frozen gel pack can be placed next to the sample inside the shipping container. The container with the sample should be kept in a cooler up to the time of shipping.

The sample must reach the laboratory in time so that analyses can commence within 24 hours after initial sampling.

9.4.6 BACTERIOLOGICAL ANALYSIS

A protocol on Microbiological Examination of Molluscan Shellfish is found under Appendix 9.

9.4.7 BACTERIOLOGICAL DATA INTERPRETATION

A summary of this subject prepared by Mr. M. Neufeld is attached under Appendix 9.1.

9.5 QUALITY CONTROL PROGRAM

Each processor is responsible for instituting and maintaining a quality control program that meets the approval of the Department.

A quality control program will consist of three functions:

1) QUALITY ASSURANCE - where the objective of the Q.C. program is defined in terms of operational and product standards.

2) PROCESS CONTROL - where action paths for achieving the standards described above may be implemented through proper sanitation procedures and good processing techniques.

3) QUALITY VERIFICATION - where the processor will measure the degree of his goal accomplishment by evaluating the product and the degree of compliance to the process control.

9.5.1 PROGRAM APPROVAL

COMPLIANCE:

The processor must have a well-defined Quality Control Program that is approved by the Department. In addition, it must have the facility and technical expertise to perform the evaluation procedures. Those operators not equipped with laboratory facilities may make arrangements to send the samples to an accredited commercial laboratory.

Any commercial laboratory selected to do the analyses must have a demonstrated capability to perform the analytical procedures specified by the Department and must be prepared to participate in split sample evaluations with the Department upon request. The Department will reserve the right to inspect and evaluate the methodology and all data at any time.

- parallel sampling shall be conducted by Inspection officers from time to time to verify that the depuration process and the accuracy of the analytical data submitted by the commercial laboratory is satisfactory.

9.5.2 RECORD KEEPING

Up-to-date, accurate and verifiable records on the product, the process operation, and the product distribution forms an essential part of the quality verification function. Record ommission or poor record keeping practices are evidences of an unacceptable quality control program.

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Production records for purification or depuration must be kept on the following as minimum requirements:

1. Product Control:
   a) The lot number and size.

   b) The harvest location and date.

   c) The name of the master digger or digger.

   d) The bacteriological results of the pre-depuration and post-depuration samples.

   e) The final weight of the depurated product.

   f) The lot number and the distribution of the final product in terms of where, who and when.

2) Operation Control:

   a) The lot number, the batch or tank number of the depuration process, and the quantity in each tank.

   b) "Time-in" and "Time-out" in hour - day - month - year.

   c) The time and duration of the 24 hour tank washdown.

   d) The flow rate chart (continuous recording).

   e) The time when visual inspection of the U.V. system was done to assure functional acceptability. A record of individual U.V. tube in the system shall be kept to ensure that the quartz tubes are replaced when the transparency decreases.

   f) The water temperature, salinity, dissolved oxygen, and turbidity of the water.

   g) Observatins or comments on any process interruption.

9.6 PROGRAM COMPLIANCE VERIFICATION:

Inspection officers will verify the processor's Quality Control Program from time to time. Any deficiencies in the program must be corrected promptly by the processor. Failure to do so or non-compliance to regulatory requirements may result in plant decertification.

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9.7 REFERENCES:

1) Devlin, I.H. and Neufeld, W. 1971. Oyster Depuration Plant, Ladysmith, B.C. Fisheries Service, Department of the Environment.

2) Devlin, I.H. 1973. Operation Report: Oyster Depuration Plant, Ladysmith, B.C. Fisheries & Marine Service, Environment Canada.

3) Neufeld, N., Tremblett, A. and Jackson, M. 1975. Clam Depuration Project, Ladysmith, B.C. Fisheries & Marine Service, Environment Canada.

4) Rowell, T.W. et al. 1976. Soft Shell Clam Depuration, Digby, Nova Scotia. Fisheries & Marine Services, Tech Report No. 687, Environment Canada.

5) Furfari, S.A., and Bond, D.M. 1976. Newburyport, Massachusetts, Plum Island Clam Purification Plant Studies, U.S. Department of Health, Education, and Welfare, Public Health Service Bureau of Disease Prevention and Environmental Control, National Center for Urban and Industrial Health, Water Supply and Sea Resources Program Northeast Marine Health Sciences Laboratory, Narragansett, Rhode Island.

6) Furfari, S.A., Adams, A.N., and Miescier, J.J. 1974. Soft Clam Depuration Plant Studies, Newburyport, Massachusetts, Department of Health, Education, and Welfare, U.S. Public Health Service, Food and Drug Administration, Northeast Technical Services Unit, Davisville, Rhode Island.

7) Furfari, S.A., Miescier, J.J., and Carr, W.E. 1974. Depuration Study - Soft Clams, Highlands, New Jersey, Department of Health, Education, and Welfare, U.S. Public Health Service, Food and Drug Administration, Northeast Technical Services Unit, Davisville, Rhode Island.

8) Miescier, J.J. 1976. Memorandum - Depuration Monitoring Program at Three Soft Clam Purification Plants in Maine, Department of Health, Education, and Welfare, U.S. Public Health Service, Food and Drug Administration, Northeast Technical Services Unit, Davisville, Rhode Island.

9) Furfari, S.A. 1979. Memorandum - Soft Clam Depuration Plant, Searsport, Maine - Additional Data, Department of Health, Education, and Welfare, U.S. Public Health Service, Food and Drug Administration, Northeast Technical Services Unit, Davisville, Rhode Island.

10) Furfari, S.A. 1966. Depuration Plant Design. Environmental Health Series, Food Protection, Public Health Services, U.S. DHEW, PHS 999-FP-7:7.

11) Huntley, B.E. and Hammerstrom, R.J. An Experimental Depuration Plant - Operation and Evaluation. Chesapeake Science Vol. 12, No. 4, p. 231 - 239 December 1971.

12) MacMillan, R.B. and Redman, J.R. Hard Clam Cleansing in New York. Commercial Fisheries Review, Reprint No. 903.

NOTE: The above list is not current.